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LECTURES

ON THE

COMPARATIVE ANATOMY AND PHYSIOLOGY

OF THE

INVERTEBRATE ANIMALS,

DELIVERED AT THE ROYAL COLLEGE OF SURGEONS.

BY RICHARD OWEN, F.R.S.

HUNTERIAN PROFESSOR TO THE COLLEGE.

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TO

WILLIAM COOKE, M.D. M.R.C.S.

FOUNDER AND TREASURER

OF

THE HUNTERIAN SOCIETY OF LONDON,

This Volume

OF

HUNTERIAN LECTURES ON THE INVERTEBRATE ANIMALS

IS DEDICATED

BY A SINCERE ADMIRER OF HIS VIRTUES

AND TALENTS.

ADVERTISEMENT.

THE present Volume is not a reprint of that on the same subject, published in 1843. The difference between them is in some measure indicative of the progress of the anatomy and physiology of the Invertebrate Animals, during the ten years which intervened between my first and last course of Lectures on that subject.

My friend and former pupil, Mr. W. White Cooper, having published his notes of the Lectures of 1843, in numbers, as they were delivered, time was not allowed to add references to the original authorities for many of the facts and opinions quoted in those Lectures: in the present Work, I have endeavoured to supply that omission according to the plan adopted in the volume on the Anatomy of Fishes: and some additions have been made of contributions to Invertebrate Anatomy and Physiology up to the date of publication.

Royal College of Surgeons, London,
May, 1855.

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HUNTERIAN LECTURES.

1852.

INTRODUCTORY LECTURE.

CHARACTERS AND CLASSIFICATION OF ANIMALS.

In entering upon a description of the Animal Kingdom, the naturalist's first and greatest difficulty is to determine its bounds. The same difficulty meets the anatomist, and must meet whoever undertakes to write on any particular quality of animals in general.

LINNÆUS, the great framer of precise and definite ideas of natural objects and terse teacher of the briefest and clearest expressions of their differences and diagnoses, divided them into three kingdoms, and characterised them as follows: —

> "LAPIDES, corpora *congesta*, nec *viva*, nec sentientia.
> " VEGETABILIA corpora *organisata* et *viva*, non sentientia.
> " ANIMALIA, corpora *organisata* et *viva* et *sentientia*, sponteque se moventia." *

In other words — minerals are unorganised; vegetables are organised and live; animals are organised, live, feel, and move spontaneously.

By organisation is meant such an internal cellular or cellulo-vascular structure as relates to the reception of fluid matter with the power of altering that matter and adding it to the alterative structure, the fluid being on that account called "nutritive," and the actions it is subjected to, "assimilation" and "intussusception." As these acts are not explicable on any known chemical or mechanical principles, they are called "vital" acts, and so long as they are continued the plant or animal is said to "live." A mineral or unorganised body can undergo no change save by the operation of mechanical or chemical forces; and any increase of its bulk is due to the addition of like particles to its exterior: it augments not by "growth" but by "accretion."

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* I. tom. i. p. 11.

Organised beings differ so much more from the unorganised than they do from each other, that the co-equality of the three Linnæan kingdoms of nature is no longer admitted, and the primary division of natural bodies is into "organic" and "inorganic," the former being collectively designated "organisms." For the distinction of these into two kingdoms, moreover, the Linnæan diagnosis no longer suffices. Nothing seems easier than to distinguish a plant from an animal, and in common practice as regards the more obvious members of both kingdoms no distinction is easier; yet as the knowledge of their nature has advanced the difficulty of defining them has increased, and seems now to be insuperable. Not that the lack of such power of definition is any loss to the Naturalist, if he has gained, instead, a truer conception of the fundamental unity of all organic nature.

Any circumscription of the Animal Kingdom must, therefore, be arbitrary, as will, I think, be evident from the following considerations.

Linnæus was not aware that many movements in unquestionable animals, that seem to be "spontaneous," are not so. Experiment had not proved that all those of Hartley's first class * depending on nervous influence, "which is detached down the motory fibres before reaching the brain," are unaccompanied by sensation, and independent of volition.† It has, indeed, been remarked with regard to this difficulty, that "if we always possessed the means of determining where consciousness and spontaneity *do* and *do not* exist, we should have comparatively little difficulty in drawing a definite line of demarcation between "plants and animals." ‡ Yet, in point of fact, we should then have merely a psychical character, which, in reference to other characters purely physiological, anatomical, and chemical, might prove after all to be an artificial one, drawing the boundary-line as arbitrarily as would be done by any other single character. But taking the power of self-motion, irrespective of its cause in living beings, if Linnæus meant "locomotion," this truly is as striking a characteristic of a large proportion of the Animal Kingdom as the fixed or rooted state is of a still larger proportion of the Vegetable Kingdom: but the vegetative fixity of the individual is a character which advances pretty far into the animal series. Not only are most polypes and a few echinoderms adherent to the place of their growth, but the whole class of cirripedes and some genera both of articulate and molluscous animals, e. g. *Serpula* and *Ostrea*, are cemented by their shells as immoveably to the rock on which they grow as are the sea-weeds that float beside them from their adherent base. On the other hand, many microscopic single-celled plants, as well as the ciliated zoospores or embryos of the *Vaucheria** and other algæ, and of the sponges, have a more rapid locomotion than some of the polygastric animalcules enjoy; although in neither case, probably, does it arise from a distinct act of volition. The movements of the oscillatoriæ, and the more partial shrinkings of the sensitive-plant from the touch, show that "motion" merely, whether of the whole or of the parts of a living organism, will not determine to which kingdom it belongs.

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* II. Vol. i. p. 97.

† III. p. 190, where the author, after detailing certain experiments, concludes from them, "that there is a property of the sentient and motory system of nerves, which is independent of sensation and volition."

‡ IV. p. 182.

Blumenbach, who appreciated the insufficiency of the psychical character from "spontaneous motion," adopted an anatomical one:— "Plants absorb their nutriment by means of numerous fibres placed at the lower end of their bodies: animals have a simple opening at their upper or anterior extremity, leading to a capacious bag, into which they introduce their food:" † Boerhaave ‡ had long before said that the food of plants was absorbed by external roots, and that of animals by internal roots; and Hunter's favourite anatomical character for animals was the "mouth and stomach." But the free parasitic genus *Gregarina* §, with its contractile cell-wall, which is soluble in acetic acid, and many of the freely moving infusoria, have no mouth nor alimentary canal; and there is nothing that can be properly called "stomach" in the cestoidea. The cellular parenchyme of tapeworms is traversed by canals more analogous in character to those which take the place of the digestive cavity in sponges. The sap-vessels, and the whole system of intercellular spaces, with their outlets in the stomata, of plants, exhibit an analogous arrangement. Carbonic acid, the nutritive material in plants, passes through the pores of the elongated canals of the intercellular spaces and is taken into the surrounding cells as formative material; just as albumen and the hydrates of carbon are introduced by the stomata of the tapeworm into the longitudinal canals, and pass through their pores into the surrounding vacuolæ or cells: the same materials, in a coarser form, passing by the more obvious mouth into the wider digestive sac of the higher animals. There is no essential or well-defined distinction of assimilative structure here: the difference is at most one of form and proportion of the internal cavities and of their external openings: they are the same as to function in plants and animals. The more free and locomotive the organism, the more capacious the internal receptacle for the matters to be assimilated, the characteristic differences of form fading away in the passage from the pendant parasites and the polypes to the astomatous polygastria, the sponges, and plants proper. So that if the presence of absorbent pores and assimilative cells, instead of a mouth and stomach, be deemed a Vegetable characteristic, then this, like the rooted character, mounts up a certain way into the Animal Kingdom.

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* V. † VI. p. 4. ‡ CL. p. 64. § VII. p. 10.

When the chemist entered upon his valued investigations into the changes which living organisms wrought upon surrounding media and those media upon them, he found that plants and animals differed in their behaviour in these respects. Plants exhaled oxygen, animals carbonic acid: the gas which was food to plants was poison to animals; animals inspired the oxygen which plants exhaled. Thus the balance of the gases in the atmosphere was beneficially maintained by the antagonistic actions of the two kingdoms. And in a general way this is true, but the chemical antagonism fails as a boundary line where we most require it, as we approach, viz., the confines of the two kingdoms. Wöhler * has shown that some of the free and locomotive Polygastria, *e. g.*, *Chlamidomonas pulvisculus*, *Euglena viridis*, *Frustulia salina*, eliminate pure oxygen, as the ultimate metamorphosis of their tissues: and on the other hand, Drs. Schlossberger and Döpping † have proved that mushrooms and sponges exhale carbonic acid. The green-coloured matter called "chlorophyll" which is common in most plants, exists in the Polygastria, in the green Planariæ, and the fresh-water polype.

As regards the conversion of the surrounding elements into their own matter, animals combine carbon, hydrogen, oxygen, and nitrogen to form the proximate principles of most of their tissues, which are thus "quaternary" compounds; whilst the tissues of plants are in general "ternary" compounds of carbon, hydrogen, and oxygen, and sometimes, as, *e. g.*, the cellulose substance, only "binary" ones of carbon and hydrogen. But if the presence of nitrogen in the organic tissues be taken as an animal characteristic, then we find it descending pretty far into the vegetable series, the element being present in the algæ, the fungi, and almost all cryptogamia. On the other hand, it has been shown by Schmidt* that some animal tissues are binary compounds, as *e. g.*, the mantle of the *Frustuliæ* and the thick cellular tunic of the *Ascidiæ*.

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* VIII. 1843. p. 206.

† Ib. bd. lii. p. 119.

Thus whilst it may be affirmed in a general way that plants *decompose* and animals *recompose* carbonic acid, the one fixing the carbon and yielding the oxygen, the other freeing the carbon in combination with oxygen taken from the atmosphere; that the plant exhales *less* water, and the animal *more* water, than it imbibes; that whilst the plant *fixes* ammonia and uses its elements for the production of organic compounds, the animal *sets free* azotised substances which speedily resolve themselves into ammoniacal compounds;— the beneficial antagonism can only be predicated in a general way of the more complex or typical members of each kingdom respectively, and will not serve as a rigorous basis of definition in the lower approximated forms where the aid of the chemist has been most wanted for that purpose.

The physiologist has asserted that plants alone can subsist on inorganic matter, and that animals depend upon plants for combining the elements into binary and ternary compounds essential to animal support.† And this also is in some degree true: the lichen that first clothed the granite rock must have converted the inorganic elements into cellular tissue. Animals, as a general rule, subsist on vegetable or on animal matter, or on both. But no proof has been given that the *Frustuliæ* and other astomous polygastria, which separate oxygen in excess, do not effect this by reducing the carbonic acid of the atmosphere, and fixing the carbon, in order to produce their fats and hydrates of carbon; or that they do not, in like manner, assimilate their ammonia either directly, or by taking the nitrogen of the atmosphere into the required combination; and so by its subsequent combination with the elements of the fats and hydrocarbonates, produce their proteine compounds and albuminates. Still less proof or probability have we that the typical or higher organised forms of vegetation could flourish without the support of decaying organised tissues, superadded to the air and water.

Ehrenberg‡ seems to have rested from his analysis of the distinction between plants and animals, on arriving at considerations offered by the generative function, and accordingly refers the "*Desmidiæ*," "*Diatomaceæ*," and "*Closteriæ*" to the animal kingdom, which he characterizes by "the power of increase by voluntary division," superadded to self-motion. But growth by elongation and bisection of the cells is very frequent if not universal in the more simple algæ; whilst propagation by spontaneous fission is the common mode of increase of the single-celled plants which constitute yeast (*Torula cerevisii*) and the colouring matter of red snow (*Protococcus nivalis*).

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* IX. p. 34.

† X. Vol. i. p. 2.

‡ XI. p. 88.

All living organs are continually receiving additions to their substances; and so long as these exceed in quantity the parts removed, they are said "to grow." Plants seem to grow as long as they live; but if the tree and other compound kinds be rightly regarded as organic associations of individual phytons, then these, when fully developed into the form of the leaf, the sepal, the petal, or the pistil, abide, like the polypes of the compound coral, without further growth, until the period of their decay or fall. And if this philosophic interpretation of the "tree" be rejected and the common notion of its individuality be held to be the truer one, it will as little assist in differentiating the plant and the animal by the character of growth: for the compound zoophyte must then be regarded as a many-mouthed individual, and any climacteric cessation of its growth can be as little predicated of it, as of the compound individual plant. But in regard to both trees and zoophytes it is plain that there is a certain term of growth, even for the compound whole; for most species have a characteristic maximum of size, otherwise we should not see the Elm of 50 years surpassing the Yew of 600 years: and no term of life would bring the Elm or the Yew to an equality of size with the mighty Boabdad (*Adansonia*).

The creatures that appear least equivocally to enjoy growth during the whole term of their existence are the *Trout*, the *Pike*, the *Anaconda*, the *Testudo elephantopus*, and the like cold-blooded vertebrate individuals: although as the rate of growth, which is always slow, becomes slower as age advances, they seem, during the few years that a naturalist can watch an aged individual of these long-lived species, to be stationary in regard to their growth. The records of unusually large specimens of such cold-blooded animals always associate such uncommon size with far advanced age, and imply that there is no definite period arresting their growth as in the warm-blooded vertebrates. Still, however, as in trees and zoophytes, the recognised average size characteristic of different species of fishes and reptiles, which all start from a germ-cell of nearly the same minuteness, shows plainly that there is a specific limit of growth for each. And this at least is certain, that the "continually receiving additions during the term of existence",* however understood, helps us no way towards the discrimination between plants and animals.

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* V. p. 182.

Thus, after reviewing the different characters by which it has been attempted to distinguish the special subjects of the botanist and zoologist, we find that neither sensation and motion, the internal assimilating cavity, the respiratory products, the chemical constitution of the tissues, nor the source of nutriment, absolutely and unequivocally define the boundary between the animal and vegetable kingdoms. We can only recognise the plant or animal when a certain number of their supposed characteristics are combined together.

A rooted organism, exhaling oxygen, with tissues chiefly composed of cellulose or of binary or ternary compounds, is, without question, to be called a "plant." An irritable or locomotive organism, with a mouth and stomach, with gelatinous or albuminous tissues, or chiefly composed of quaternary compounds, exhaling carbonic acid, is as certainly an "animal." But such "plants" and "animals" are specially defined members of one and the same great family of organised beings.

An internal assimilative cavity, whether in the form of cells, canals, or bags, is essential to all. The movement of a part, when stimulated, is a property continued from the higher organised forms far down into those that manifest the combined characteristics of the vegetable kingdom, as, *e. g.* in the *Mimosa pudica* and the *Dionæa muscipula*, as to which the statement that such movements were destined solely for the furtherance of *formative* operations, would be purely gratuitous. Locomotion also crosses the supposed line, and is an endowment of the embryos or spores of the sea-weeds. On the other hand, the rooting or fixation of the organism is continued upwards from the vegetable kingdom into the Radiate, the Articulate, and the Molluscous divisions of the animal kingdom. The cellular and cellulo-vascular forms of the assimilative cavity, common to plants and sponges, is repeated in the cestoid entozoa, the astomous polygastria, the rhizopoda, and in the early embryos of all higher animals. Tissues of binary compounds are found in polygastria and ascidiæ, and the chitinous coverings of insects and crustaceans have a much closer resemblance to ligneous fibre than to proper animal tissues. The presence of starch is of itself quite inadequate as a ground of distinction, even were it proved to form part of the proper cell-walls. And, on the other hand, nitrogen combines with carbon and hydrogen to constitute the chief tissues of the sponges, algæ, and fungi. These exhale carbonic acid like well-organised animals, and the polygastria exhale oxygen like typical plants.

Thus the groups of characters that are essential to the true definition of a plant and an animal interdigitate, so to speak, in that low department of the organic world from which the two great branches rise and diverge. Every naturalist or physiologist is at liberty, of course, to adopt any one of the characters that have been supposed to divide the two kingdoms; but the boundary so defined will be artificial, and each different character will bisect the debateable ground in a different latitude of the organic world.

Animals and plants, then, are not two natural divisions, but are specialised members, of one and the same great group of organised beings. When a certain number of characters concur in the same organism, its title to be regarded as a "plant" or an "animal" may be readily and indubitably recognised; but there are very numerous living beings, especially those that retain the form of nucleated cells, which manifest the common organic characters, but without the distinctive superadditions of either kingdom. Such organisms are the *Diatomaceæ*, *Desmidiæ*, *Protococci*, *Volvocinæ*, *Vibriones*, *Astasiæ*, *Thalassicolæ*, and *Spongiæ*; all of which retain the character of the organised fundamental nucleated cell, with comparatively little change or superaddition.

In a work treating expressly of the animal organisation I am unwilling to include more than the zoologist may fairly lay claim to, and I therefore look for certain combinations of characters as qualifications for admission, although occasional illustrations of organic functions will be derived from the indeterminate organisms above mentioned.

Thus if irritability of parts or locomotion of the whole be not accompanied with mouth and stomach, it must be manifested by proximate tissues of quaternary compounds, and the cell-walls and fibres must consist of albuminous or gelatinous matter, or be soluble in acetic acid.

If some of the tissues of an organism are binary compounds, yet if they include a stomach with a mouth, and are also associated either with irritable parts or a power of locomotion, such organism will be referred to the animal kingdom.

When to a mouth and alimentary canal are superadded definite muscular and nervous filaments, a heart, a breathing apparatus, and generative organs, no doubt of the animality of the organism can be entertained.

Having thus laid down the grounds on which I have marked out that higher division of organised bodies which is the proper subject of the studies of the zootomist, I proceed next to offer a few remarks on the leading varieties and grades of structure in the animal kingdom, in so far as they are guides to its classification.

Little useful progress can be made in Comparative Anatomy without some knowledge of Zoology. Zoology is the key to the nature and habits of the animals of which Zootomy unfolds the structure. Some knowledge of natural history and of the principles of classification, therefore, is essential to the comprehension of the connection between structure and habits, on which the utility of Anatomy in the advancement of Physiology mainly depends.

The classification of animals is not now what it was in the time of Linnæus. I do not mean merely to say that animals are differently arranged, but the objects and principles of that arrangement are very different.

Linnæus in his *Systema Naturæ* wished to give, as it were, a Dictionary of the Animal Kingdom, by reference to which you might as readily ascertain the place of the animal in his system as that of a word in a lexicon by merely knowing its first and second letters. To this end, Linnæus selected a few of the most obvious characters for the establishment of his groups.

Taking, for example, a certain number of incisor teeth and the pectoral position of the mammæ, as the characters of his first order of animals, he thereby associated man with the monkeys and the bats. But, independently of the psychical endowments which place the human species far above the lower creation, it may readily be conceived that great differences of organisation must exist in animals which enjoy the erect position on two feet, in those which climb by having four hands, and in those which fly by having their anterior members in the form of wings.

External and arbitrary characters, selected merely for the convenience of their appreciation, thus tend to the association of very differently organised species, and as often separate into very remote groups of an artificial system two animals which may have very similar anatomical structures. Of this we have several examples in the Linnæan subdivisions of the class of fishes, the orders of which are characterised by the easily recognisable position of the fins. Linnæus's attention was particularly directed to the very variable position of the ventral pair of fins, which are the homologues of the hinder limbs in land animals. In some fishes, as the pike and many other fresh-water species, the ventral fins are at some distance behind the pectoral fins, or in their usual place — these formed the order *Abdominales:* in others, as the perch, the ventral fins are attached beneath the thorax — these constitute the *Thoracic* order: in others, as the cod, you find the ventral fins in advance of the pectorals, or under the throat — such species formed the *Pisces jugulares* of Linnæus: lastly, those species in which the ventral fins are altogether wanting, as the eel, formed the *Apodal* order.

Such a system has the advantage of enabling the collector to refer with great facility any fish to its artificial order: but you can scarcely rise and diverge. Every naturalist or physiologist is at liberty, of course, to adopt any one of the characters that have been supposed to divide the two kingdoms; but the boundary, so defined, will be artificial, and each different character will bisect the debateable ground in a different latitude of the organic world.

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Aristotle thought he had found this primary differential character in the blood, recognising as blood only the circulating fluid which was red coloured. He accordingly divided the *Zoa* into *Enaima* and *Anaima*, or the sanguineous and exsanguineous animals. For a long time no advance was made beyond this early step in the primary division of animals. It was at length discovered that many of the exsanguineous animals of Aristotle did actually possess blood, though differing in colour from that of the so-called sanguineous species. This led, however, only to a nominal improvement in the classification; the *Enaima* were called "red-blooded," the *Anaima* "white-blooded" animals. It was reserved for Cuvier* to discover, in the course of his minute dissections of the lower animals, that an extensive class of worms had red blood circulating in a closed system of arteries and veins; and this discovery first materially affected the value of the character applied by Aristotle to the primary groups of the animal kingdom.

The Annelides, or red-blooded worms, could not, however, be combined with birds, beasts, and fishes, in a natural system, since they differed from them widely in almost every other particular of their organisation.

Some other character was therefore sought for, since it became obvious that the colour of the blood led to an artificial combination of species. Lamarck† thought he had discovered the desired character in the vertebral column, this structure being present in all the Enaima of Aristotle, and absent in all his Anaima. Lamarck proposed, therefore, the name of *Vertebrata* for the one class, and *Invertebrata* for the other. Now it will be observed that the Invertebrata are grouped together by a negative character; and I know not any instance where such a character has been employed in zoology, in which very differently organised species have not been associated together. What indeed can be predicated in common of the snail, the bee, and the polype, than that they are animals, have no red blood, no vertebral column, and the like negations? It was obvious also that the Vertebrata and the Invertebrata were not coequal groups, and the idea of equivalency or proportion, as well as that of likeness, ought always to govern the labours of the classifier.

In the attempt to remedy this defect, the discovery was made that the vertebral column was subordinately related to a condition of a much more important system in the animal body than the skeleton, viz. the nervous system. Cuvier* thereupon applied himself with indefatigable industry to ascertain the arrangement of the nerves in the Invertebrata, and after a long series of minute and elaborate dissections, he discovered three modifications of that system, each of equal importance with that which governed the vertebral character of the red-blooded animals of Aristotle. Cuvier, accordingly, proposed to divide the animal kingdom into four primary groups or sub-kingdoms, viz. *Vertebrata*, *Mollusca*, *Articulata*, and *Radiata*.†

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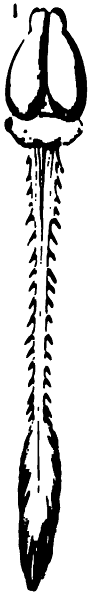
* XII. t. ii. p. 515.

† XIII.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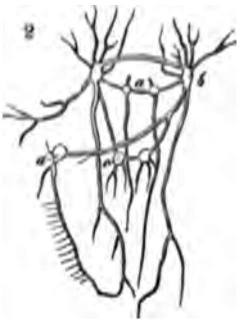
It is due to Hunter‡ to state that the general results of his dissections of the nervous system are expressed in the definitions of the same leading types as those of Cuvier; but he made the minor differences which he had detected in the *Vertebrate* series equal to those primary types of the nervous system which now characterise the *Mollusca* and *Articulata* of Cuvier,—a view which would have led to erroneous results if applied to the classification of the primary groups of animals.

The sub-kingdom *Vertebrata*, or *Myelencephala*, is characterised by the disposition of the principal mass of the nervous system in a median axis, consisting of the brain and spinal chord (*fig.* 1.), situated along the dorsal aspect of the body, behind the heart and digestive system; and inclosed in a bony or cartilaginous case, constituting a vertebral column. The organs of the five senses, sight, hearing, smell, taste, and touch, are almost always present.

The respiratory organs communicate with the pharynx, or anterior part of the alimentary canal.

The mouth is provided with two jaws, placed one above or in front of the other.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The blood is red.

The heart is a compact muscular organ, having never fewer than two cavities, an auricle and ventricle, propelling the blood through a closed system of arteries and veins.

The muscles surround the bony or gristly levers on which they act.

The locomotive members never exceed two pairs.

The sexes are distinct and no species is parthenogenetic.

In the sub-kingdom *Mollusca*, or *Hetero-*

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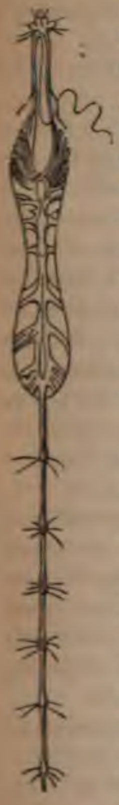
* XIV. † XV. ‡ X. Vol. iii, p. 10.

gangliata, the principal centre of the nervous system bears the form of a ring, surrounding the gullet, from which the nerves radiate, often unsymmetrically, to different parts of the body (*fig.* 2.): the brain is represented by ganglions above (*a*) or at the side (*b*) and below the gullet; other ganglions (*c d*) are developed in other parts of the body. The form of the body corresponds with the disposition of the nervous system, and is commonly unsymmetrical. In a single order (*Cephalopods*) the muscles originate from an internal rudimental cartilaginous skeleton: in the rest they are attached only to the skin, which forms a soft envelope in which there are developed in many species one or two, rarely more, calcareous plates, called shells.



The blood is colourless, or not red; the heart compact, muscular, and propelling the blood through a closed system of arteries and veins, or venous sinuses. *

The respiratory organ is never absent; and, with the exception of one family (*Ascidians*), the cavity containing it receives, or opens near, the anus.

The *Mollusca* are diœcious or hermaphrodite: some of the lowest organised species are parthenogenetic.

The third primary division of the animal kingdom, viz. the *Articulata*, has the brain in the form of a ring, embracing the gullet: a double ganglion above the tube supplies the chief organs of sense: from the sub-œsophageal ganglions two chords are extended along the ventral surface of the abdomen, and are, in most species, united at certain distances by double ganglions, which give origin to the nerves of the body-segments and their appendages (*fig.* 3.). From the symmetrical disposition of the nervous centres, I have called this sub-kingdom *Homogangliata*. The body presents a corresponding symmetrical form. The skeleton is external, and consists of articulated segments, of frequently an annular form: the articulated limbs in those species which possess them have a similar condition of the hard parts, in the form of a sheath, which encloses the muscles.

The respiratory organs commonly open upon the sides of the body; rarely near the anus, and never communicate with the mouth.

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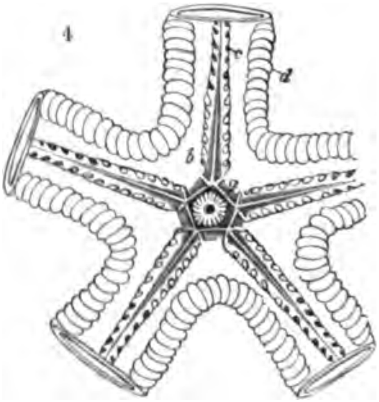
* The latter phrase is added, in the present edition, because the term "closed system" has been supposed to imply a particular form of the veins, viz. the tubular: and has been objected to by the supporters of the hypothesis that the blood in many Mollusks is diffused in interspaces or lacunæ of the viscera (XVI. p. 292.). I have shown, however, that these supposed lacunæ are sinuses closed or formed by the proper tunic of the veins. See XVI. p. 315. pl. 4., and pl. 1. of the present volume.

The jaws, when present, are lateral, and move from side to side.

The heart is situated in the back, is often vasiform; and the veins are frequently in the form of large, irregular sinuses [*]; there is always a circulation, and the blood is red in one class (*Anellides*).

Most *Articulata* are diœcious: a few are hermaphrodites: still fewer are parthenogenetic.

The *Radiata*, or fourth primary division of animals in the system of Cuvier, is so called because most of the species comprising it have their parts arranged around an axis, on one or several radii, or on one or several lines extending from one pole to the other. The nervous system, when traces of it have been visible, is also arranged in radii (*fig.* 4.). It does not present the homogangliate or heterogangliate type. In one family only (*Holothuriadæ*) is there a distinct respiratory system: the other characters assigned by Cuvier are negative ones.



I have already observed, that there is no instance in which animals, grouped together by negative characters, have formed a natural assemblage; nor is the sub-kingdom *Radiata* of Cuvier an exception to this rule.

The truth is simply that the anatomy of this immense assemblage of low-organised animals is not yet sufficiently understood; and, consequently, general propositions, and at the same time positive ones, like those which define the Vertebrate, Molluscous, and Articulate sub-kingdoms, cannot be enunciated.

Much has unquestionably been done in this field of Natural History since the time of Cuvier, and attempts have been made, with various degrees of success, to subdivide the *Radiata* according to positive characters.

The binary division, which I proposed in 1835 [†], was founded on the following considerations. The *Radiata* of Cuvier, in which the nervous system could be most unequivocally traced in a filamentary form, present an alimentary canal as a distinct tube, with a mouth

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[*] First demonstrated by Hunter, in the Crustaceans and Insects. See "Treatise on the Blood," p. 174., and X. vol. ii. p. 138. pl. xvii.

[†] Syllabus of the Lectures on Comparative Anatomy, given at the Medical School of St. Bartholomew's. 8vo.

Kingdom ANIMALIA.
Province *Vertebrata*.
Class MAMMALIA.
AVES.
REPTILIA.
PISCES.

Province *Articulata*.
Class ARACHNIDA.
INSECTA.
CRUSTACEA.
EPIZOA
ANELLATA.
CIRRIPEDIA.

Province *Mollusca*.
Class CEPHALOPODA.
GASTEROPODA.
PTEROPODA.
LAMELLIBRANCHIATA.
BRACHIOPODA.
TUNICATA.

Subprovince *Radiaria*.
ECHINODERMATA, BRYOZOA, ANTHOZOA, ACALEPHÆ, HYDROZOA.

Subprovince *Entozoa*.
CŒLELMINTHA, TURBELLARIA, STERELMINTHA.

Subprovince *Infusoria*.
ROTIFERA, RHIZOPODA, POLYGASTRIA.*

LECTURE II.

POLYGASTRIA.

I PROPOSE first to invite your attention to a class of animals, the most minute, and apparently the most insignificant of created beings. It might almost seem needful to apologise for the design of trespassing on your time and patience during one or two lectures with the Anatomy and Physiology of creatures which are wholly invisible to the naked eye. But we are too apt to let our judgments of the importance of objects be unduly influenced by first impressions, especially by those of magnitude or the contrary, which deeper insight into their true nature and value rectifies.

The active atoms about to be described, for the knowledge of whose very existence we are indebted to the microscope, are by no means the least complex of organised beings; those which will be the subject of the present lecture belong to the higher division of organic nature, and most of them manifest the distinctive properties of animals in a striking and unequivocal manner.

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* A Glossary and explanation of the scientific terms will be added to the concluding Lecture.

Leeuwenhoek was little aware how large a prospect of organic life he was opening to our view, when, in the year 1675, he communicated to his scientific friends his discovery of the little bell-shaped animalcule (*fig.* 5.), now known as one species of an immense class, and called the *Vorticella convallaria.* His observations were published in one of the early numbers of the "Philosophical Transactions": * much discussion on the subject ensued, and called forth the wit of the philosophers of the day. However, the records multiplied, and now we have obtained a view of the Infusoria, which shows them to be the most widely diffused and by far the most numerous of all the forms of organised life. Wherever Ehrenberg went in his travels with Humboldt, he there detected with his microscope some of the manifold forms of these animalcules; and wherever his pupils have repeated his observations, the same phenomena have been presented. Not only in fresh water, but almost over the whole ocean, species of Infusoria abound; if you catch a drop of water from the spray that rises from the paddle of the steam-boat, in it you will hardly fail, with an adequate magnifying power, to detect some specimens of this class. When Sir James Ross and his companions, in accordance with their directions, took up the film from the surface of the Antarctic Sea, that film, in its dried remains, was found to consist of siliceous cases of the Infusoria; in the mud brought up from the depths of the ocean, at the highest southern latitudes sounded by the deep-sea line, they were found; and they have also been detected in the sand adhering to specimens dredged up at Melville Island, by Captain Parry; so that from north to south poles, and in all intervening latitudes, these animalcules are diffused, and extend the reign of animal life beyond that of the vegetable kingdom.

You may obtain specimens of Infusoria almost at will. If you skim a small portion of the green matter, which in summer time mantles the surface of a stagnant pool, place a drop of this in the object-holder of a microscope, and examine it with a glass of a quarter of inch focus, you will find it teeming with animal life; you will see numerous little objects, of one or other of the forms depicted in these diagrams (*figs.* 5, 6, 7.), leisurely coursing or darting with rapidity across the field of view, or rolling over, or gyrating on their axes. If you examine in like manner a drop of water in which has been infused any vegetable or animal substance, and which contains the particles of such substances in a state of decay or decomposition, you will find such infusions similarly tenanted with these active animalcules; they have been termed from this easy and common mode of procuring them, the animals of infusion, or *Infusoria*.

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* XVII. p. 821.

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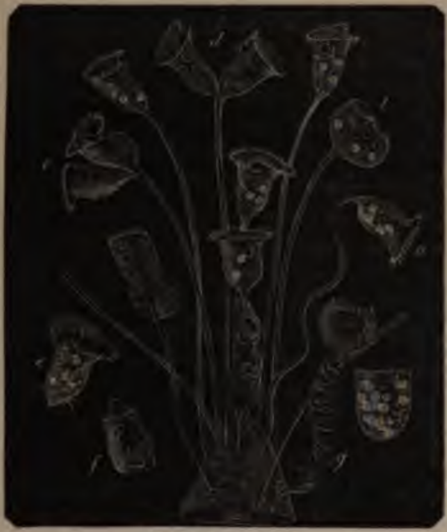

Vorticella nebulifera.

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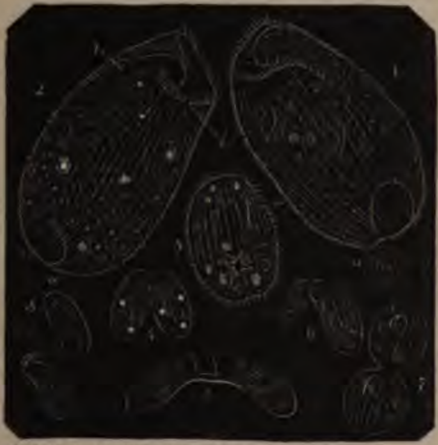

1, 2. Spirostomum virens; 3—8. Glaucoma scintillans.

The earlier microscopical observers confounded all the minute living objects which they thus met with under that term; but the progressively increasing powers of definition at the command of later observers have led to the removal of the single-celled locomotive plants (*fig.* 7.), together with the embryos of polypes, worms, and insects, from this motley and heterogeneous group, and have restricted it to those animals which, in their fully developed state, manifest a form of body more or less amorphous, devoid of radiated prehensile arms, without definite locomotive members, commonly moving by means of minute superficial vibratile cilia more or less diffused over the surface of the body, or aggregated in circular groups near the head, where they produce by their successive oblique action the appearance of rapidly rotating wheels. Only the largest species of Infusoria are provided with the last specified arrangement of vibratile cilia, and these "wheel-animacules," as they are termed, being endowed with a higher type of organisation, more especially of the digestive system, constitute a distinct class of Infusorial animalcules, of a higher grade of organisation than the more diffusely ciliated group (*figs.* 5. & 6.), which is the subject of the present lecture.

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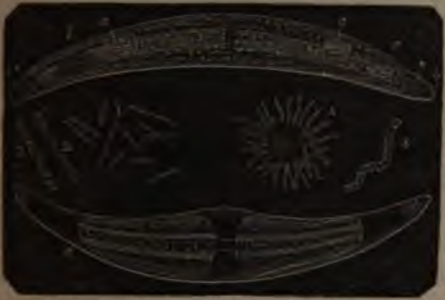

1–3. Vibrio subtilis ; 4, 5. Vibrio rugula ; 6, 7. Closterium.

The species of this group are essentially nucleated cells, with a superadded organisation for locomotion, digestion, and, in some species, for circulation and generation. The cell-wall incloses a colourless and transparent gelatinous plasma, with numerous minute and often coloured corpuscles. Particles of food when taken in are seen to occupy subspherical and subequal spaces in the same plasma, and the spaces so occupied being regarded by Ehrenberg as stomachs, he has thence proposed for this class the name of *Polygastria*, which may well be retained, although the idea of these assimilative cavities having distinct walls and intercommunicating canals be abandoned.

The most minute forms, as the species called *Monas crepusculus*, Ehr., have been estimated at the $\frac{1}{2000}$ of a line in diameter.* Of such Infusoria a single drop of water may contain five hundred millions of individuals, — a number equalling that of the whole human species now existing upon the surface of the earth. But the varieties in the size of these invisible animalcules are not less than that which prevails in almost every other natural class of animals: from the minutest *Monad* to the larger species of *Loxodes* or *Amphileptus*, which are one sixth or one fourth of a line in diameter, the difference of size is greater than between a mouse and an elephant. Within such narrow bounds might our ideas of the range of size in animals be limited, if the sphere of our observation was not augmented by artificial aids!

Many of the polygastric animalcules are naked, covered only by an elastic, transparent integument, which, in some (*Euglena*, *Amœba*), is smooth; in most is more or less ciliated. Others are protected by a shell, which consists of pure, colourless, and transparent silex. This shell may present the form of a simple shield, indicating by its position the back of the animal, as in *Euplœa Charon;* others have

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* A line is the twelfth of an inch.

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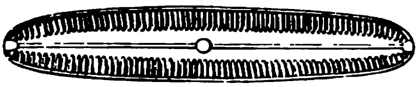

Navicula.

their flinty armour resembling a minute bivalve shell: in some, as the *Navicula*, it has the form of an elongated case, or flattened cylinder, open at both extremities (*fig.* 8.): it is sometimes straight, sometimes bent, like the Australian boomerang; it may present the form of a reticulated cone (*fig.* 9.), or a discoid case (*fig.* 10.): in short, the varieties of the siliceous shells of the Infusoria are as numerous as those of the calcareous shells of the Mollusca. But whatever their form, the superficies of these delicate microscopic objects is generally sculptured with a beautiful, well defined, and more or less complicated pattern, which makes it easy to recognise the species, and distinguish them from one another.

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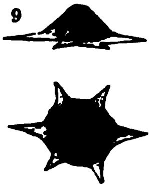

Dictyocha.

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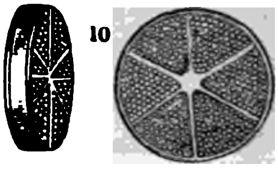

Actinocyclus, bivalve.

Most of these animated minims are locomotive and free; a few, as the *Vorticellæ*, are attached to foreign bodies by a long and highly irritable and contractile pedicle; others, as the *Gomphonema*, are appended to the extremities of the branches of a dichotomously divided stem.

In *Loxodes Bursaria* (fig. 18.) the parietes of the body, which equal about one-sixth of its transverse diameter, consist of an outer, firm, colourless substance supporting the cilia, and of an inner, softer matter, in which green globules are imbedded. The outer layer is marked by numerous close-set, fine grooves, extending obliquely or spirally, and in opposite directions, over the whole outer surface, giving it an "engine-turned" or reticulate character. The cilia are attached to the eminences defined by the decussating grooves, and are of considerable length, when seen in the quiescent, dying, or decomposing animacule.*

The green corpuscles imbedded in the deeper layer are spherical nucleated cells, corresponding in their chemical characters with the chlorophyll-corpuscles of *Vaucheria* and other Algæ; the similar corpuscles which float in the fluid contents of the body are seen in circulation close to the inner surface of the parietes, in the direction indicated by the arrows in *fig.* 18.

The locomotive Polygastria propel themselves through the water by the action of their vibratile cilia, which are sometimes generally diffused, as in *Leucophrys* (*fig.* 13.), *Loxodes* (*fig.* 18), *Bursaria*, *Nassula*; sometimes aggregated in longitudinal rows, as in *Amphileptus*; or in transverse circles along narrow bands, as in *Trichodina*; or they are limited to the region of the mouth, as in the *Vorticellæ*, (*fig.* 5.), indicating the passage to the higher or Rotiferous group. The body in *Peridinium* is girt with an oblique hoop of long cilia. In most Polygastria the cilia are longer than they are commonly represented, and the marginal cilia of the flat body in *Stylonychia*, and the ventral ones in *Oxytricha* and *Euplotes*, are of such relative size as to give the species a myriapodous character, and are used, like little feet, to creep along the stems of the chara, and other minute vegetable plants. In some Polygastria cilia are supported on one (*Amblyophis*) or two (*Chlorogonium*) tentacular processes, which wave to and fro and create currents in the water; in *Peridinium tripos* there are three such prolongations; but true jointed locomotive members are never developed in any of this minute and primitive race of animated beings. They retain, throughout life, those simple vibratile organs which produce the rotatory movements in the ova of Mollusca whilst imprisoned in their nidus, which are the agents of analogous movements of the Mammalian ovum in the fallopian tube, and which are probably common to the embryos of all classes of animals at that early period which the Polygastric Infusoria seem permanently to represent.

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* XVIII. t. xxxiv. fig. vii. *Bursaria vernalis*.

These cilia, the outward instruments of locomotion in Infusoria, and which are retained on a greater or less proportion of the mucous surfaces of all animals, most probably vibrate by virtue of the contractility of their tissue. Ehrenberg, however, directs attention to their expanded base in some Polygastria, and especially to a radiated structure there which he conceives to indicate the disposition of the muscular fibres moving such cilia.

In observing the motions of the Polygastric Infusoria, one perceives that they avoid obstacles to their progress; rarely jostle one another; yet it is difficult to detect any definite cause or object of their movements. Some species, it is true, prey upon animalcules of their own class, and will gorge an individual of nearly their own size, which they attract by the currents in the water caused by the oral vibratile cilia, or entangle and inclose by those organs.* But the greater number of the class subsist on the minute atoms of the decomposing animal and vegetable substances of the fluids or infusions in which they exist, — particles which do not require a definite pursuit, since they are inert and generally diffused throughout the infusion.

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* XIX. p. 202.

The motions of the Polygastria have appeared to me, long watching them for indications of volition, to be in general of the nature of respiratory acts, not attempts to obtain food or avoid danger. Very seldom can they be construed as voluntary, but seem rather to be automatic ; governed by the influence of stimuli, within or without the body, not felt, but reflected upon the contractile fibre ; and therefore are motions which never tire. We may thus explain the fact which Ehrenberg relates—not without an expression of surprise—namely, that at whatever period of the night he examined the living Infusoria, he invariably found them moving as actively as in the day-time ; in short, to him it seemed that these little beings never slept. Nor did this appear to be merely the result of the stimulus of the light required to render them and their movements visible ; since when they were observed upon the sudden application of light without any other cause of disturbance, they were detected coursing along at their ordinary speed, and not starting off from a quiescent or sleeping state.

Evidence of muscular action in the Polygastria is afforded by the contraction and change of form of the entire body. These changes are so rapid, extensive and various in certain species that it is impossible to refer their bodies to any definite shape: such form the genus *Proteus* of Müller, and the family *Amœbæa* of Ehrenberg. No definite arrangement of nervous matter has yet been detected in the Polygastric Infusoria; but its presence is indicated by the coloured eye-speck in certain genera : and nervous conductors of impressions are no less requisite for reflex than for voluntary motions.

The eye-speck (*fig.* 11. *c.*), as the bright pink spot has been interpreted by Ehrenberg, is usually single, *e. g. Amblyophis, Euglena, Chlorogonium ;* but is double in *Distigma :* it is absent in the *Astasiæa*, which have other close relations to the single-celled plants.

In many Polygastric animalcules, *e. g. Vorticella, Loxodes*, there is a permanent cavity (*fig.* 18. *a.*) in the interior of the cell-like body, which opens externally. This aperture, which may be termed the mouth, is sometimes sessile, sometimes placed upon

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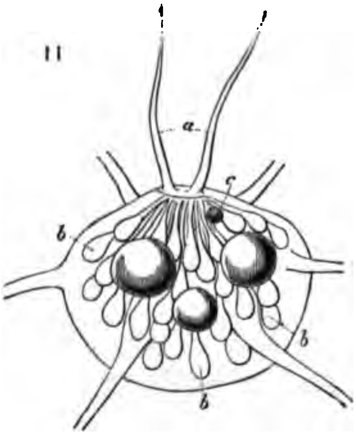

Monad of Volvox.

a long extensile neck, as in *Lacrymaria;* in some monads, if Ehrenberg have rightly interpreted its presence and position, it is provided with a long tentacle or a pair of tentacles (*fig.* 11. *a.*); it has a conspicuous fringe of cilia in some Polygastria (*fig.* 13. *a.*); in other species it is unequivocally armed with a curious dental apparatus, consisting of a series of long, slender and sharp teeth, arranged side by side, in the form of a cylinder, as in *Chilodon* and *Nassula* (*fig.* 14. *a*, *a*).

Later Microscopists have failed to detect the mouth or the canals converging towards it from the green globules, which canals Ehrenberg has described and figured in the constituent monad of the *Volvox globator* (*fig.* 11).* Siebold† refers, indeed, the *Volvocinæ* to the same group of the Vegetable Kingdom as the *Closterinæ* and *Bacillariæ;* and he cites the unusually large species of the genus *Opalina* (*O. Ranarum*), parasitic in the intestines of the Frog, as affording indubitable evidence of the absence of any mouth, and of the power of these astomatous Infusoria to absorb fluid nourishment by generally diffused surface-pores, as shown by the bile-stained contents of their body. In certain Astomata, with long cilia or filaments, *e. g. Actinophrys Sol,* when a prey is brought within their reach the filaments incline towards and bend over it, intercrossing each other and pressing the prey to the surface of the animalcule. That part of the surface yields; the prey, whether it be a smaller animalcule or plant-sporule, sinks into the substance of the body, which closes over the prey without leaving any trace of its passage: functionally such passage performs the office of a mouth; just as the vacuolæ in the central plasma, which receive the nutriment so taken in, perform the office of stomachs: but neither such mouths nor stomachs have proper parietes or a permanent existence‡: and the same may be said of any part of the external parietes of the animalcule through which insoluble or indigestible parts of the food are extruded.

In the higher forms of the Polygastria provided with a determinate mouth armed with teeth, the larger objects of food are seized and bruised by them: the dental cylinder first expands in front to receive the morsel, and, as this passes along, the cylinder contracts in front and dilates behind, so as to push the food into the digestive cavity.

If such larger animalcules with unequivocal mouths be removed from their native infusion to a drop of clear water, and after they have fasted a few hours, a drop of the solution of pure indigo or carmine be added, the fine particles of these colours will be greedily swallowed, and will soon be seen to fill successively a number of pyriform or spherical cavities (*fig.* 13. *b.*) in the interior of the animal. In some species these cavities have been so shown to be very numerous; and if, with Ehrenberg, we call them stomachs, they afford a very interesting example, in these early forms of animal life, of the irrelative repetition of this most essential and characteristic organ of the animal. Ehrenberg has described and figured certain definite arrangements of these digestive cavities, as well as of the alimentary canal, to which he states that they are appended. In the Monads, and many other of the more minute species of the Polygastria, he affirms the stomachs to arise by separate tubular pedicles from a common mouth, as shown in *fig.* 11., copied from his great work. Such species have no intestine, no anus, and are said to be *anenterous*. In others, he believes the so-called stomachs to be appended to an alimentary canal (*Polygastria enterodela* Ehr.): which canal may be bent into a loop, and describe a circle, with the anus opening near the mouth, as in *Vorticella* (*fig.* 12.); or it may pass in a straight line through the axis of the body, as in *Enchelis;* or form several flexuous curves in its passage from the mouth to the opposite extremity of the body, as in *Leucophrys* (*fig.* 13.). But sometimes, as in the Kolpoda, neither the mouth nor anus is terminal in position.

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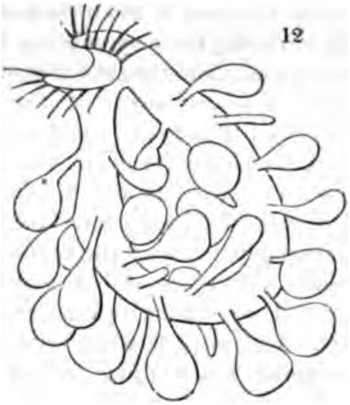
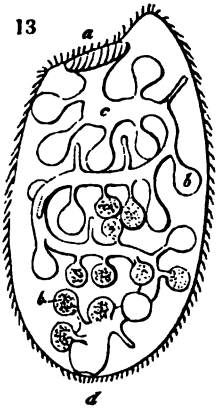
* XL, tab. iv. fig. 1. 13.

† X. p. 7.

‡ XIX. p. 198, pl. xvii.



Vorticella.



Leucophrya.

It has been objected to this interpretation given by Ehrenberg of the nature of the vacuolæ which receive and assimilate the nutrient molecules, that certain species, as the *Enchelis pupa,* will swallow another animacule nearly equal to itself in bulk, and thereby undergo a total change in the form of its body; but this may only imply great dilatability of the œsophagus or common canal, such as we observe in the boa constrictor, which becomes in like manner deformed after gorging a goat or other animal much thicker than the snake itself; for doubtless the little cavities successively receive and digest, like the stomach of the boa, the dissolved parts of the swallowed prey. But it has been further objected that the cavities are not fixed in definite positions, but are seen constantly, though slowly, moving, and apparently rotating through the general cavity of the animal. This phenomenon, first observed by Focke in 1835*, led him to dissent from Ehrenberg's account of the alimentary canal, at least in regard to the *Loxodes Bursaria*, in which not only the balls of coloured food, but the green corpuscles, which are constant elements in the organisation of the animalcule, are subject to a regular circulating movement, like the granules of chlorophyll in the leaf-cells of the *Valisneria spiralis:* both food and granules being carried along by the corresponding motion of the gelatinous fluid or plasma in which they are suspended.

Analogous phenomena observed by Rymer Jones†, Meyen‡, Erdl§, and Siebold‖, have accumulated a body of evidence against Ehrenberg's determinations which the sub-circular arrangement of the food-filled spaces in *Vorticella*, and their subspiral disposition in *Leucophrys*, are inadequate to repel. The only expressly organised internal digestive apparatus in the stomatode *Polygastria* is a simple wide and very dilatable cavity (*fig.* 18. *a.*), extending into the middle of the body from the mouth; having a ciliated inner surface in *Loxodes*, and probably other species. The spaces in the surrounding soft tissue into which the digesting parts of an engulphed prey, or the particles of carmine and indigo, pass, are usually filled with a clear fluid, and they have no constant and specially organised canals of communication with the common digestive cavity. In some species this cavity has a second opening or anal outlet (*Nassula elegans*): in most species the same opening serves both as mouth and vent.

Although a vascular system with proper parietes has not been detected in any Polygastrian, all the species which possess a mouth and digestive cavity also manifest one or more pulsating vesicles, varying as to shape and position in the different species. During the diastole the vesicle is filled by a clear colourless fluid; in the systole it disappears. The fluid is the product of the digestive process, and answers to both chyle and blood in the higher animals; by the action of the pulsatile cells it is driven through the soft parenchyme and its stagnation there is prevented. In the genera *Vorticella*, *Epistylis*, *Loxodes*, in *Amœba diffluens*, *Paramæcium Kolpoda*, *Stylonychia*

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* XX. p. 785.

† XXI. p. 121.

‡ XXII.

§ XXIII.

‖ XXIV. p. 16.

mytilus, and *Euplotes patella*, the pulsating sac is single and subcircular, and situated at one side of the body. In *Actinophrys*, *Bursaria* and *Trachelina* there are two pulsating sacs: in *Loxodes Bursaria* one of them is situated in the anterior third, the other in the middle third part of the body (*fig.* 18. *v*, *v*.). In *Arcella vulgaris* from three to four pulsating sacs have been observed. In *Nassula elegans* four round hearts follow one another along the dorsal region of the body; in *Trachelius Meleagris* there is a row of from eight to twelve such hearts. The contractile sac presents the form of a long pulsating vessel in *Spirostomum ambiguum* and in *Opalina Planariarum*. In *Paramecium Aurelia* canals extend from the circular sac in the form of rays. The *Cryptomonas ovata* and *Opalina Planariarum* are the only species of the Astomatous Infusoria in which the contractile sac has been observed.*

By the analogy of the gills of the acephalous Mollusks we may regard the mechanism for renewing the surrounding oxygenised medium upon the respiratory surface, to be the superficial vibratile cilia, the action of which upon the water is necessarily attended in the free Infusoria with a reaction which rolls the little animalcule through its native element and produces the semblance of a definite voluntary movement.

In the saline springs at Königsborner and Rodenberg, Wöhler† observed that the green mantle, formed of innumerable individuals of *Frustulia salina*, *Chlamydomonas pulvisculus* and *Euglena viridis*, was raised from the surface, here and there, by bubbles of gas. He collected the gas, and found it to be almost pure oxygen. This interesting discovery clearly indicated a respiratory process like that of plants. The minute green corpuscles, partly fixed in the inner layer of the integument, partly circulating in the contained fluid of the Polygastria, and regarded by Ehrenberg as ova, correspond in their nature with the chlorophyll corpuscles of *Algæ*, and most probably perform an analogous function, fixing the carbon of the atmosphere in the hydro-carbonates, and evolving oxygen.

Perhaps the most marvellous part of the organisation and economy of the Polygastric Infusoria is that which relates to the function of generation: the only one which does not necessarily require a special organ for its performance — a proposition which will be quite intelligible when the essential nature of the generative process is understood.

The part which Ehrenberg describes as the "testis" is the usually large sub-spherical corpuscle (*fig.* 17. *n*.), situated at or near the middle of the body in the Polygastria. It presents an extremely fine granular appearance, and is much firmer than the loose tissue in which it is embedded. Its colour is commonly a dull yellow by transmitted light; and in the more minute species it is highly refractive: upon the whole it presents the nearest resemblance to the matter of the spermatozoa, which are themselves modifications of a cell-nucleus; and from the close analogy which the so-called "testis" presents to the "nucleus" in both the animal and vegetable cell, it has now generally received the latter name. It is commonly single, and presents the spherical or oval form in *Chlamydomonas* (*fig.* 17. *n n.*), *Euglena, Actinophrys, Arcella, Amœba, Bursaria, Paramæcium, Glaucoma, Nassula, Chilodon, Loxodes* (*fig.* 18. *n.*), &c. There are usually two nuclei, one behind the other, in *Amphileptus Anser, Trachelius Meleagris*, and *Oxytricha Pellionella:* four nuclei have been observed in *Stylonychia mytilus.* More numerous nuclei, partly united, like a row of beads, have been seen in *Stentor polymorphus, Spirostomum ambiguum*, and *Trachelius moniliger.* The nucleus assumes the elongated form in *Vorticella convallaria, Epistylis leucoa*, and *Bursaria truncatella*, in which it is slightly bent: in *Euplotes Patella* it is horse-shoe shaped, and in *Stentor Roeselii* is spirally twisted.*

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* XXIV. p. 20.

† VIII. 1843, p. 206.

The nucleus performs an essential part in, and seems to govern, the act of propagation by spontaneous fission, which is the most common mode in the Polygastria. In Tab. xxxvi. of Ehrenberg's great work†, fig. vii. 13. shows, in *Chilodon cucullulus*, the nucleus divided in the direction of the long axis of the body: in fig. 14. the division of the whole body in the same direction has commenced: in fig. 15. it is nearly completed. Figure 16. shows the preliminary division of the nucleus transversely, and the succeeding figures illustrate the transverse fission which follows. In most well-fed Polygastria, after the preliminary division of the nucleus, which may be obscured from view by the coloured contents of the body, the first sign of the approaching fission is usually a clear line which may be discerned stretching itself transversely across the middle of the body and indicating a separation of the contents into two distinct parts. The containing integument next begins to contract along this line, and the creature to assume the form of an hour-glass (*fig.* 6, 7. and *fig.* 14.): this, though an uncontrollable, seems to be a spontaneous action, and the struggle of each division to separate itself from its fellow indicates an impulse in each to assume its individual and independent character; the which they no sooner effect than they dart off in opposite directions, and rapidly acquire the normal size and figure. In the *Vorti-*

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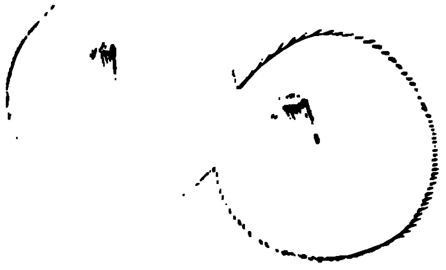
* XXIV. p. 24.

† XI.

[illegible] species, we have examples of spontaneous fis-



[illegible]

sion in the longitudinal direction, which commences at the mouth, fig. 2, a, and extends to [illegible] the [illegible] and contractile sacs, from which one or both of the new-formed individuals [illegible] fig. 4, c. Both the longitudinal and transverse modes of fission may take place in the same species, as in the *Gonium*, [illegible] and as in the *Chilodon cucullulus* [illegible] observed, in *Loxodes Bursaria*, that the two individuals produced by longitudinal fission had almost the same size and shape as the previous single individual; whilst the two resulting from transverse fission seemed longer to remain as mere halves of a divided individual. Sometimes one of the individuals or halves [illegible] the longitudinal direction will set up another act of fission before it has quite separated from its fellow. The circulation of the [illegible] is arrested during the process of spontaneous fission.† In some species this spontaneous fission, which corresponds in so [illegible] manner with the earliest phenomenon in the development of the ovum in the higher animals‡, is arrested before its completion, but the partially separated individuals continue in organic connection and form compound animals, sometimes in the form of long chains, sometimes branched, sometimes expanding to form a spherical bag, as in the well known *Volvox globator*, which was long deemed a single individual of a peculiar species. New spherical groups of Volvoces

[illegible]

[illegible] first saw a Polygastrian in the act of dividing, supposed it to be [illegible] in 1765, first recognised its real character.

‡ This analogy I pointed out in illustration of the cleavage-process of the ova [illegible] in my "Lectures on Generation," delivered in 1840. It is alluded to in the following passage in Dr. M. Barry's "Memoir on the Nucleus of the Animal and Vegetable Cell," [illegible] "Between the appearances presented by the mammiferous germ during the passage of the ovum through the oviduct, and certain Infusoria, including the *Volvox globator* as figured by Ehrenberg, the resemblance first mentioned by Professor Owen is so remarkable that we cannot avoid the belief, that the same process operates in both."

17.), I see a resemblance to the two, four, eight, &c. groups of cells in the mammiferous ovum too striking not to suggest that the process of formation must be the same in both: the essential part of this process consisting in the division of the pellucid nucleus."* Ehrenberg, who, as we have seen, calls this nucleus of the Polygastria the "testicle," views its division simply in the relation of the necessity of each individual resulting from the general fission having such an organ: meaning that each monad, developed by spontaneous fission, is perfected, as regards its so-called testis, by the spontaneous division of the previous testis, and not by the formation of a new one. But this is not the mode in which the eye, or the circle of teeth, or the pulsating sac, is gained by the second individual from the fission: the division usually takes place so as to include the original organ in one or in the other moiety; and that in which it may be wanting gets the organ by a special and independent development of it. The constancy of the preliminary fission of the nucleus would therefore show that it related rather to the totality of the act itself than to the partial completion of the individual in respect of its being provided with a particular male organ of generation. How then, we may inquire, does the division of the nucleus relate to the performance of the general act of spontaneous fission? Our hope of any insight into this mysterious relationship would be from some light to be derived by analogous phænomena. But with what phænomena is the one in question analogous? Obviously most closely with those which have been observed in the successive fissions of the impregnated germ-cell of those ova, such *e. g.* as the ova of the Ascaris (*figs.* 48-59.), best adapted to give a view of the fission analogous to those which the perseverance of Ehrenberg enabled him to trace in the spontaneous fission of the monad.

If this spontaneous fission of the nucleus and germ-cell preliminary to the division of the germ-yelk has not been seen in the ova of other animals, it is because hitherto only the coarser phænomena of such division of the yelk in the ova of Medusæ, Mollusca, Fishes, Frogs, &c. have been noticed. In Dr. Barry's observations however on the development of the germ-mass in the pellucid ova of the rabbit†, phænomena were noted closely analogous to those described by Siebold and Bagge‡ in the ovum of the entozoon.

In reflecting on the cleavage phænomena in the monad and the ovum — that a central something is first established, and the consequence thereof — I have been led to draw the same conclusion with respect to both, and to regard the establishment of the special centre as the cause of the confluence of the parts around it, and to call it "a centre of attractive and assimilative force." * Since the pellucid centre of the germinal body has not divided from the necessity of endowing the moiety to be separated by the subsequent fission with a particular organ required for its individual completeness, I infer that the same preliminary act in the monad was not solely for the purpose of providing its separated moieties with their respective testes, but that it had a higher significance.

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* XXVI. p. 24. † XXVII. p. 320-324. ‡ XXVIII.

As the pellucid centre in the ovum is the result of impregnation or the reception of the matter of the spermatozoon, so it may be concluded that the nucleus of the monad is of a nature similar to, if not identical with, that of the spermatozoon. It was doubtless a gross view of its nature and analogies to regard it as the homologue of the whole preparatory organ of the spermatic fluid, such as is required in the higher animals; because as the germ-cells exist in the body of the Polygastria without the organ called ovarium, so we ought to expect that the essential matter of the sperm would likewise exist without a special testicular envelope.

The objection, however, to Ehrenberg's determination of the nucleus as the "testis," that it has never been observed to produce spermatozoa, is akin to that which has been opposed to his determination of the ova, viz. that the young have never been seen to quit them and leave the shell behind. Neither of these objections will apply to the view of the nucleus as the essential matter of the sperm, and of the germ-cells as the essential elements of ova and embryo.

A spermatozoon is doubtless a very general form of the essential matter of the sperm: but in tracing the modifications of the spermatozoa from mammalia down the scale of animal life, we find them gradually reduced to the head or nuclear part, and discern in the vibratile caudal appendage an accessory relating to the passage of the fertilising principle to the germ-cell, rather than to its essential operations when arrived there.

The best microscopical examinations of the spermatozoa show that they consist of a homogeneous or minutely granular substance, which exhibits a yellow amber-like glitter. The nucleus of the Polygastrian offers the closest resemblance to this character of tissue. And it is not uninteresting to notice the close analogy of the modification of form which the nucleus of some of the larger Polygastria, *Stentor*

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* XXIX. p. 203. XXX. p. 66.

Roeselii e.g., presents to the spirally disposed elongated head of the spermatozoon in the Torpedo, Pelobates, and the Passerine birds.

Besides the more frequent and commonly observed mode of propagation by spontaneous fission, the Polygastria generate in the more normal and perfect way. This, indeed, has been rarely seen, and has been denied by some.[*] No doubt the term 'ova' has been applied to many of the minute granules and nucleated cells in the soft parenchyme of the Polygastria, without that evidence which is requisite to produce conviction of the accuracy of such determination. The green-coloured nucleated cells, for example, which circulate in *Loxodes*, like the chlorophyll-particles in the leaf-cells of Valisneria, are more probably concerned in fixing carbon and eliminating oxygen, like their answerable parts in plants. But the essential part of the ovum, *e.g.* the germ-cell, must exist to set on foot those processes of development which lead to the formation of the embryo in the viviparous species of Polygastria. And I may here cite the remark of a distinguished chemist in support of the partial accuracy at least of Ehrenberg's ascription of ova to the Infusoria. In the simplest animals in which the ova or ovarium can be distinguished with certainty, it is the only organ in which oil or fat is accumulated. The yellowish masses which Ehrenberg discovered, by the aid of a high magnifying power, on each side of the siliceous carapace in the gelatinous envelope of the *Frustulia salina*, when chemically tested, yield abundance of fat: they disappear, *e.g.* when treated with æther, and the latter then contains a brownish fat in solution. This result of Schmidt's minute analysis leads that accurate observer to regard Ehrenberg's determination of those yellowish masses, as ovaria, to be well founded.[†] The formation of locomotive germs in, and their escape from, the interior of a Polygastrian, appears to have been seen by Dr. Arlidge [‡] in the *Trichodina pediculus*, in which he describes the phenomena as a kind of internal gemmation. The best description of the viviparous generation of a Polygastrian is that given by Focke [§] and Cohn [||] in *Loxodes Bursaria*. In this species, at the latter end of autumn and in winter, there may be seen within the body one or more large globules, which, when from six to eight in number, present, by mutual pressure, a parenchymatous structure (*fig.* 19.). They are of different sizes, from $\frac{1}{125}'''$ to $\frac{1}{100}'''$ in diameter, well-defined, almost colourless, filled with fine granules and one or more hyaline nuclei (*h*); and they are inclosed by two contractile cysts, defining the individual life in each. These germs lie free in a clearly defined cavity of the body, which opens by a narrow canal through a projecting portion of integument, upon an infundibular orifice with a labiated border. Cohn saw these germs escape by this canal and orifice, the canal expanding, and the germ yielding to the pressure and becoming a narrower and longer body *in transitu* (*fig.* 18, *e*). The parturition lasted twenty minutes, giving ample time to observe and delineate a germ half in and half out of the mother. As soon as one end of the germ enters the surrounding water, it begins to ciliate and create a current, which accelerates the birth: this completed, the young rests awhile beside the mother, then separates itself and moves freely through the water. It is cylindrical, thrice as long as broad, obtuse at both ends: but the embryos vary in size from $\frac{1}{125}'''$ to $\frac{1}{70}'''$ in length. They are colourless, sometimes present little tubercles at one end, have no mouth, are beset by fine and long cilia, and differ so much from the parent that their relationship could not be recognised without observation of the birth. They have accordingly been referred to a distinct genus, viz. *Cyclidium*, by Ehrenberg.* As soon as one germ is born, out follows another; and Cohn thinks that when only one or two are seen in a Loxodes, the rest have already escaped; and that many are developed as a rule. The position of the outlet varies; and Cohn once saw two embryos escaping by two distinct apertures, which indicates that the 'vulva' like the 'anus' may be casual and temporary. The pulsatile vesicles of the parent are not disturbed in their actions during the parturition. The rotation of the chlorophyl-cells is arrested so long as a germ is inclosed in the body: but it is resumed, and goes on more rapidly, as soon as the parent is relieved of her burden. One of the moieties of a longitudinally splitting Loxodes may sometimes be seen to contain germs, and these also to be excluded even before the other moiety has become separated: thus the two distinct generative processes may go on simultaneously.

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[*] XXIV. p. 23.

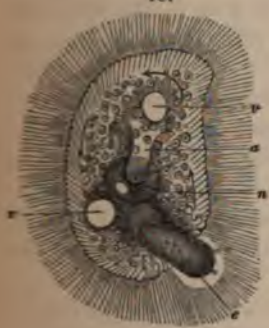
[†] IX. p. 36.

[‡] XXXI.

[§] XXXII.

[||] XVIII.

18.



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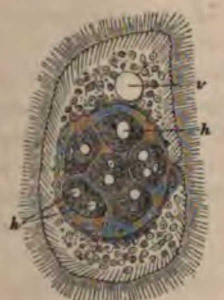

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* *Cyclidium margaritaceum*, XI. p. 387., pl. xxii.

The *Vorticella microstoma* secretes, and surrounds itself by, a smooth cyst, in which all its previous organisation is resolved into a minutely granular fluid, save the pulsatile sac, which ceases to beat, and the elongated bent nucleus. Two processes of development start from this partial dissolution and passive pupal condition. In the one (acinetiform) process the nucleus contracts itself into a shorter and thicker shape; two pulsatile sacs are developed; and a new integument is formed, from which radiate groups of long vibratile filaments. The creature thus starts afresh into locomotive life as an *Actinophrys;* and then developes a hollow stem, and becomes the *Acineta mystacina* of Ehrenberg.* In this the nucleus expands, attracts and assimilates the surrounding granular fluid, and becomes developed into a pyriform monad with a circular band of vibratile cilia: the embryo escapes from the *Acineta*, swims off, and lays the foundation of a new colony of *Vorticellæ*. In the second (monadiform) process of development the nucleus of the encysted pupa elongates and divides by spontaneous fission into many nucleoli: each of these exercises its attractive, assimilative, and modifying properties upon the contiguous granular fluid: as many minute simple locomotive monads are the result, which escape from a rent in the cyst, and swim abroad, doubtless to undergo further changes, completing the metagenetic cycle.†

By virtue of these diversified modes of multiplication, the powers of propagation of the most diminutive of organised creatures may be truly said to be *immense*. Malthusian principles, or what are vulgarly so called, have no place in the economy of this department of organised nature. To the first great law imposed on created beings, "increase and multiply," none pay more active obedience than the Infusorial animalcules.

Attempts have been made to calculate approximatively their rate of increase.

On the 14th of November, Ehrenberg divided a *Paramæcium aurelia*, a polygastric animalcule measuring one twelfth of a line in length, into four parts: which he placed in four separate glasses.

On the 17th of November, the glasses numbered 1 and 4, each contained an isolated Paramæcium, swimming actively about. The pieces in numbers 2 and 3 had disappeared.

On the 18th there was no change.

On the 19th each animalcule presented a constriction across the middle of the body.

On the 20th No. 1. had propagated five individuals by transverse spontaneous division: in No. 4. eight individuals had in like manner been generated.

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* XI., tab. xx., fig. x.

† XXV*, pp. 478—485, XVIII., fig. 1—13.

On the 21st no change had taken place.

On the 22nd there were six nearly equal-sized individuals in No. 1., and eighteen individuals in No. 4.

On the 23rd, the individuals were too numerous to be counted.

Thus it was demonstrated that this species of Polygastrian would continue for six days without any diminution of reproductive force, and that on one day a single individual twice divided, and one of its divisions effected a third fission.

A similar experiment on a *Stylonychia Mytilus*, an animalcule one tenth of a line in length, was attended with nearly the same results; it was well supplied with the green nutrient matter, consisting of the *Monas pulvisculus*, and on the fifth day the individuals generated by successive divisions were too numerous to be counted.

The conditions of this parthenogenetic mode of propagation appear to be the close conformity of the entire Polygastrian to the condition of the nucleated cell, the attractive and assimilative force of the nucleus, and the large proportion of unchanged secondary cells in its organisation.

Cells predominate in the tissues of the vegetable kingdom, the lower members of which consist exclusively of them, and have been thence called 'plantæ cellulares:' the lowest of all consist of a single nucleated cell.

The animal kingdom starts from the same elementary beginning: a cell-wall forms the smooth elastic and contractile integument of the *Gregarina* — a genus of microscopic parasites which infest gregariously the internal cavities and canals of insects and worms — in which a fluid with granules, and a firm nucleus with sometimes a nucleolus, are the sole representatives of organs or viscera. Yet the power of the *Gregarinæ* to live and grow independently by assimilating foreign nutriment, the vital contractility of their tegumentary tunic, their chemical composition and their definite forms, with such well-marked specific characters, in a few instances, as the *Greg. brevirostris* and *Greg. Sieboldii* present, render their interpretation by Kölliker as a low and primitive form of parasitic animal, the most accordant with actual physiological and zoological knowledge.*

The *Gregarina* is a single-celled animal, which differs from the single-celled plant by the vital contractility of its tissue, and the solubility of its cell-wall in acetic acid. Devoid of mouth, stomach, or any other organ properly so called, it reduces our definition of an animal to the difference indicated in the preceding comparison.

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* VII. p. 10.

The *Rhizopoda* are but little better organised, although they are locomotive, and provided with long slender branched filamentary feet, and have their simple contractile tissue protected, in most species, by chambered foraminiferous shells.

The ciliated *Polygastria* exhibit the next step in the progress of individualising a higher independent embodiment of animal life. A firm central nucleus in which, as in *Gregarina* and *Amœba*, resides the mysterious property of spontaneous division, indicates, however, their essential character as animated cells, and recalls to mind the bold figure in which Oken long since indulged, when he affirmed that the higher animals, and even Man himself, were aggregates of Infusoria. The very step, however, which the Infusoria take beyond the primitive astomatous cell-stage of their existence, invests them with a specific character, as independent and distinct in its nature as that of the highest and most complicated organisms. No mere organic cell, destined for ulterior changes in a living body, has a mouth armed with teeth, cavities for digestion, pulsatile cells for circulating a clear plasmatic fluid, an irritable and contractile integument beset with vibratile cilia, or prolonged into tentacula.

And now you may be disposed to ask: To what end is this discourse on the anatomy of beings too minute for ordinary vision, and of whose very existence we should be ignorant unless it were revealed to us by a powerful microscope? What part in nature can such apparently insignificant animalcules play, that can in any way interest us in their organisation, or repay us for the pains of acquiring a knowledge of it? I shall endeavour briefly to answer these questions. The polygastric Infusoria, notwithstanding their extreme minuteness, take a great share in important offices of the economy of nature, on which our own well-being more or less immediately depends.

Consider their incredible numbers, their universal distribution, their insatiable voracity; and that it is the particles of decaying vegetable and animal bodies which they are appointed to devour and assimilate.

Surely we must in some degree be indebted to these ever active scavengers for the salubrity of our atmosphere. Nor is this all: they perform a still more important office, in preventing the progressive diminution of the present amount of organised matter upon the earth. For when this matter is dissolved or suspended in water, in that state of comminution and decay which immediately precedes its final decomposition into the elementary gases, and its consequent return from the organic to the inorganic world, these wakeful members of nature's invisible police are every where ready to arrest the fugitive organised particles, and turn them back into the ascending stream of animal life. Having converted the dead and decomposing particles into their own living tissues, they themselves become the food of larger Infusoria, as e. g. the *Rotifera*, and of numerous other small animals, which in their turn are devoured by larger animals, as e. g. fishes; and thus a pabulum, fit for the nourishment of the highest organised beings, is brought back by a short route, from the extremity of the realms of organic nature.

There is no primordial and self-subsistent organic matter, as Buffon taught: the inorganic elements into which the particles of organic matter pass by their final decomposition are organically recomposed, and fitted for the sustenance of animals, through the operations of the vegetable kingdom. No animal can subsist on inorganic matter. The vegetable kingdom thus stands, as it were, in the breach between animal matter and its ultimate destruction; but in this great office plants must derive most important assistance from the polygastric Infusoria. These invisible animalcules may be compared, in the great organic world, to the minute capillaries in the microcosm of the animal body, receiving organic matter in its state of minutest subdivision and when in full career to escape from the organic system, and returning it by new channels towards the central and highest point of that system. Like true beneficence, they work their good unobtrusively and unseen.

But besides the important functions which the Polygastria perform in relation to the conservation of organic matter and of the purity of the atmosphere, they likewise take their share in modifying the crust of the earth. It has been shown that some Polygastria are naked, others loricated or defended by silicious shells, of definite and easily recognisable forms and patterns in different species. Professor Ehrenberg had not long made these observations before he discovered that a certain kind of silicious stone, called Tripoli or Polierschiefer, was entirely composed of such cases — was, in fact, the *débris* of Polygastric animalcules, chiefly of an extinct species, called *Gaillonella distans*. The substance alluded to has long been known in the arts, being used in the form of powder for polishing stones and metals. At Bilin, in Bohemia, there is a single stratum of this substance, not less than fourteen feet thick, forming the upper layer of a Tripoli hill, in every cubic inch of which layer Ehrenberg estimates that there are forty-one thousand millions of individuals of the *Gaillonella distans*. It likewise contains the shells of *Naviculæ*, *Bacillaria*, *Actinocyclus*, and other silicious animalcules. The lower part of the stratum consists of the skeletons of these animalcules, united together without any visible cement; in the upper and more compact masses the infusory shells are cemented together, and filled by amorphous silicious matter, formed out of dissolved cases. Corresponding deposits of the silicious cases of these animalcules have since been discovered in many other parts of the world, some including fresh water species, others marine species of Infusoria. At Egea, in Bohemia, there is a stratum of two miles length, and averaging twenty-eight feet in thickness, of which the uppermost ten feet are composed wholly of Infusoria, including the beautiful shells of *Campylodiscus:* the remaining eighteen feet consist of the silicious cases of Infusoria mixed with a substance like pollen. The town of Richmond, in Virginia, is built on barren silicious strata, twenty feet in thickness, composed chiefly of Infusorial shells, including the well-marked *Actinocyclus* and *Coscinodiscus.* A quantity of a pulverulent matter is deposited upon the shores of the lake near Uranea in Sweden, and which, from its extreme fineness, resembles flour. This has long been known to the poorer inhabitants under the name of *Berg mehl*, or mountain meal, and is used by them mixed up with flour as an article of food: it consists almost entirely of the silicious shells of pulverised *Polygastria*, and of closely allied single-celled locomotive plants.

Most of the Infusorial formations, as the polishing slates of Cassel, Planitz, and Bilin, are, in fact, extraordinary monuments, which have handed down to us the record of the existence of polygastric Infusoria at remote periods of the history of this planet. Their minute size, elementary structure, tenacity of life, and marvellous powers of reproduction, have enabled them to survive, as species, those destroying causes which have exterminated all the contemporaneous higher forms of animals. Several species, for example, still exist, which were in being at the period of the deposition of the chalk, and which contributed their silicious remains to the flinty masses that are always more or less intermixed with cretaceous matter. Existing species of Polygastria have even been detected as low down as the Oolite. Before this discovery no remains of higher organised animals at present in existence had been detected, with the same degree of certainty, even in the cretaceous formation. A few existing zoophytes and testacea first make their appearance in the tertiary beds immediately above the chalk; hence called Eöcene, from εος, the dawn, as indicating the first dawn of the creation of existing species. The number of existing species of shells increases in the 'Miocene,' and is still greater in the 'Pliocene' tertiary strata; but the higher animals, as the *Anoplotheria*, *Palæotheria*, *Mastodons*, *Mammoths*, and other mammalian contemporaries of the Eöcene, Miocene, or Pliocene testacea, have utterly perished. The discovery, therefore, by Ehrenberg, of several, at least twenty, species, of silicious-shelled Infusoria, fossil, in the chalk and chalk marls, which are perfectly identical with those now living in the sands of the Baltic and North Sea, is a most interesting addition to the obscure history of the introduction of the successive species of animals on this planet, and must add greatly to the interest of the Infusorial class in the eyes of the naturalist and geologist. "For these animalcules," says Ehrenberg, "constitute a chain, which, though in the individual it be microscopic, yet in the mass is a mighty one, connecting the organic life of distant ages of the earth, and proving that the dawn of the organic nature co-existent with us reaches further back in the history of the earth than had hitherto been suspected."

The still existing species are by no means rare or isolated, but fill in incalculable numbers the seas of Northern Europe, and are not wanting on the tropical coasts of the globe. With reference to the operations of the invisible Polygastria at the present day on these and other coasts, I have only time to refer you to a paper by the indefatigable Berlin Professor, entitled "Observations upon the important Part which Microscopic Organisms play in the choking up of the Harbours of Wismar and Pillau; also, in the Formation of the Mud which is deposited in the Bed of the Elbe, at Cuxhaven, and upon the agency of similar Phenomena in the Formation of the Bed of the Nile, at Dongolar in Nubia and in the Delta of Egypt." "Truly, indeed," says Ehrenberg, "the microscopic organisms are very inferior in individual energy to lions and elephants, but in their united influences they are far more important than all these animals."*

LECTURE III.

ROTIFERA.

THE animal kingdom may be likened to a cone, the species of which it is constituted diminishing in number as they ascend in the scale of complexity. Rising from different parts of the basal circumference, the different groups reciprocally approximate, interweaving their mutual affinities within a progressively closer reticulation, until they finally culminate in the apex, which is crowned by Man.

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* XXXII. p. 386.

The interest with which you listened to the anatomical details of those minute creatures, which, by their low grade of structure, their extensive distribution and incalculable myriads, form the base of the animal pyramid, encourages me again to invite you to condescend from the high sphere of your habitual studies and duties to this most remote and lowly region of animal life.

Low though the *Infusoria* be, and remote from man in the scale of organisation — literally at an invisible distance from us — yet, by the aid of the optician's science and skill, analogies may be discerned in them to the human structure, which ought to enlist your sympathies with the discoveries that have been made in their Microscopical Anatomy.

Time was, and not many years ago, in this country, when that term, Microscopical Anatomy, was almost regarded as synonymous with the anatomy of the imagination: but the numerous and highly important discoveries which have been made and confirmed by observers in almost every European state, by means of the greatly improved microscopes at their command, have placed the value, the indispensability, of that instrument to the anatomist, beyond the necessity of vindication.

Some scepticism may be natural and pardonable, when the anatomy of an animalcule $\frac{1}{1000}$ of a line in diameter is attempted to be demonstrated: but trace it to its source, and you will find such incredulity to be essentially based, not merely on distrust in our means of observation, but in the difficulty of adequately conceiving the relations of size. Just ideas of these relations are essential to the acceptance and full appreciation of the discoveries which have extended for us the bounds of space; and I will ask permission to quote the words of one of our old philosophers, which bear directly on this subject, and, expressing a noble confidence in intellectual progress, shed a prophetic gleam upon the present improved powers of penetrating space.

"In consistency, I suppose some bodies to be harder, others softer, through all the several degrees of *tenacity*. In magnitude, some to be greater, others less, and many unspeakably little. For we must remember that, by the understanding, quantity is divisible into divisibles perpetually. And, therefore, if a man could do as much with his hands as he can with his understanding, he would be able to take from any given magnitude a part which should be less than any other magnitude given. But the omnipotent Creator of the world can actually from a part of any thing take another part, as far as we by our understanding can conceive the same to be divisible. Wherefore there is no impossible smallness of bodies. And what hinders but that we may think this likely? For we know there are some living creatures so small that we can scarce see their whole bodies. Yet even these have their young ones; their little veins and other vessels, and their eyes so small as that no microscope can make them visible. So that we cannot suppose any magnitude so little, but that our very supposition is actually exceeded by nature.

"Besides, there are now" (the book was published in 1655) "such microscopes commonly made, that the things we see with them appear a thousand times bigger than they would do if we looked upon them with our bare eyes. Nor is there any doubt but that, by augmenting the power of these microscopes (for it may be augmented as long as neither matter nor the hands of workmen are wanting), every one of those thousandth parts might yet appear a thousand times greater than they did before. Neither is the smallness of some bodies to be more admired than the vast greatness of others. For it belongs to the same Infinite Power as well to augment infinitely as infinitely to diminish. To make the great orb, namely, that whose radius reacheth to the sun, but as a point in respect of the distance between the sun and the fixed stars; and, on the contrary, to make a body so little, as to be in the same proportion less than any other visible body, proceed equally from one and the same Author of Nature. But this of the immense distance of the fixed stars, which for a long time was accounted an incredible thing, is now believed by almost all the learned. Why then should not that other, of the smallness of some bodies, become credible at some time or other? For the majesty of God appears no less in small things than in great; and as it exceedeth human sense in the immense greatness of the universe, so also it doth in the smallness of the parts thereof. Nor are the first elements of compositions, nor the first beginnings of actions, nor the first moments of time more credible, than that which is now believed of the vast distance of the fixed stars."*

I have said, that in the diminutive Polygastria, there might be discerned structures analogous to our own. Vibratile cilia — their sole organs of locomotion — are the first actively moving parts with which the mammiferous ovum is endowed, with which, therefore, we ourselves commence life. They are retained throughout life as a essential part of the organisation of a very extensive tract of our internal mucous membranes: and these most minute and incalculabl numerous vibrating filaments, like their homologues in the Pol gastria, know no repose. It might almost have been anticipated th the earliest possessed, and most extensively diffused organical dynam in every member of the animal kingdom, should be the most constant, if not the sole, moving power in the first-born of Fauna.

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* XXXIII. vol. i. p. 445. A similar idea had occurred to a much older philosopher:—

> "Tertia pars nulla ut possit ratione videri.
> Horum intestinum quodvis quale esse putandum 'st?
> Quid cordis globus aut oculi? quid membra? quid artes?
> Quantula sunt? quid præterea primordia quæque,
> Unde anima, atque animi constet natura, necessum est?"
>
> *Lucret.* lib. iv.

Is man liberated from one narrow spot in space, and enabled move to and fro on the surface of his little world, by virtue of internal receptacle of nutriment? So likewise is the Infusorial animalcule. Even some of the superadded complications of the digesti canal are present; the Polygastrian seizes food with prehensile orga reduces it by the action of a score of dental spines, arranged as have seen, like the teeth of the circular trephine: it is the very ty of the digestive function: assimilating and re-organising the deco posing particles of animal and vegetable matter with a hundre stomach power. That low delight, the bliss supreme of the civilis gourmand, is given most liberally where it ought to be, to the cre tures at the lowest grade of animality.

Nor is the procreative function so abundantly or so variously e joyed by any other animal as in the Polygastria: they are fissipa ous, gemmiparous, oviparous, and viviparous. In creatures who most obvious and common mode of propagation is by spontaneo fission, a power so actively exercised, as, according to Ehrenber experiments, to be productive of an incalculably rapid rate of m tiplication, it may be demanded: To what end were special org of generation developed? Yet the essential elements of these exis in the *Loxodes* and *Vorticella*, and laid the foundation of the cilia embryos which those species brought forth. If Ehrenberg be c rect in his ascription of ova to any of the Polygastria, it is reasona to suppose that the fissiparous reproduction has reference princip to increasing the numbers of individuals in the infusions, or rec batches of decayed organisms, in which they at that time exist; wh the development of fertile ova, like the germs in the multipar pupa of *Vorticella*, which long retain their latent life in the cysted state, have relation to future and different localities or coll tions of such infusions, into which the ova or germs may conveyed more easily than the entire animals, and so lay foundation of new generations of Infusoria. In the heats of su mer, for example, many of the pools and stagnant collecti of water in which Infusoria abound are dried up. Now, it is tr that certain Infusoria have the power of retaining their vital ourselves commence life. They are retained throughout life as an essential part of the organisation of a very extensive tract of our internal mucous membranes; and these most minute and incalculably numerous vibrating filaments, like their homologues in the Polygastria, know no repose. It might almost have been anticipated that this earliest possessed, and most extensively diffused, organical dynamic in every member of the animal kingdom, should be the most conspicuous, if not the sole, moving power in the first-born of Fauna.

Is man liberated from one narrow spot in space, and enabled to move to and fro on the surface of his little world, by virtue of an internal receptacle of nutriment? So, likewise, is the Infusorial animalcule. Even some of the superadded complications of the digestive sac are present; the Polygastrian seizes food with prehensile organs, reduces it by the action of a score of dental spines, arranged, as we have seen, like the teeth of the circular trephine: it is the very type of the digestive function: assimilating and re-organising the decomposing particles of animal and vegetable matter with a hundred-stomach power. That low delight, the bliss supreme of the civilised gourmand, is given most liberally where it ought to be, to the creatures at the lowest grade of animality.

Nor is the procreative function so abundantly or so variously enjoyed by any other animal as in the Polygastria: they are fissiparous, gemmiparous, oviparous, and viviparous. In creatures whose most obvious and common mode of propagation is by spontaneous fission, a power so actively exercised, as, according to Ehrenberg's experiments, to be productive of an incalculably rapid rate of multiplication, it may be demanded: To what end were special organs of generation developed? Yet the essential elements of these existed in the *Loxodes* and *Vorticella*, and laid the foundation of the ciliated embryos which those species brought forth. If Ehrenberg be correct in his ascription of ova to any of the Polygastria, it is reasonable to suppose that the fissiparous reproduction has reference principally to increasing the numbers of individuals in the infusions, or receptacles of decayed organisms, in which they at that time exist; whilst the development of fertile ova, like the germs in the multiparous pupæ of *Vorticella*, which long retain their latent life in the encysted state, have relation to future and different localities or collections of such infusions, into which the ova or germs may be conveyed more easily than the entire animals, and so lay the foundation of new generations of Infusoria. In the heats of summer, for example, many of the pools and stagnant collections of water in which Infusoria abound are dried up. Now, it is true, that certain Infusoria have the power of retaining their vitality for a long time in a state of desiccated torpidity. I shall presently have to allude to the experiments of Spalanzani and others on the wheel-animalcules, in illustration of this curious property. Some who have repeated his experiments have not succeeded in reviving the subjects after so long a period of inanimation as four years*; nevertheless, great tenacity of life is unquestionably, notwithstanding the delicate tissues of the Infusoria, a property of creatures of their grade of organisation; and what holds good of the parent, in regard to this property of latent life, must, *à fortiori*, be allowed to the ovum and encysted pupa.

The supposed act of oviparous generation, that of sending forth countless germs through the fatal laceration or dissolution of the parent's body, is most commonly observed in the well-fed Polygastria, which crowd together as their little ocean evaporates; and thus each leaves, by the last act of its life, the means of perpetuating and diffusing its species by thousands. When the once thickly tenanted pool is dried up, and its bottom converted into a layer of dust, these inconceivably minute and light germs will be raised with the dust by the first puff of wind, diffused through the atmosphere, and may there remain long suspended; forming, perhaps, their share of the particles which we see flickering in the sunbeam, ready to fall into any collection of water, beaten down by every summer shower into the streams or pools which receive or may be formed by such showers, and, by virtue of their tenacity of life, ready to develope themselves wherever they may find the requisite conditions for their existence.

The possibility that such is the design of the alleged oviparous and of the observed encysted multiparous generation of the Infusoria, and such the common mode of the diffusion of their germs, renders the hypothesis of spontaneous generation, which has been so frequently invoked to explain their origin in new formed natural or artificial infusions, quite gratuitous. If generative organs might, at first sight, seem superfluous in creatures propagating their kind by gemmation and spontaneous fission, equivocal generation is surely still less required to explain the origin of beings so richly provided with the ordinary and recognised modes of multiplication. Many experiments have, however, been detailed, in which adequate precautions appeared to have been taken to prevent the possibility of the entry of fertile germs into the fluid experimented on, after means had been taken to destroy all that it might contain. From these experiments, the mere access of atmospheric air, light, and heat to the infusions has been deemed to include all the conditions required for the primary formation of the lower animal or of vegetable organisms. The results in favour of such a view are, however, explicable by supposing that due precautions had not been adopted at the beginning of the experiment to exclude every animal or germ capable of development in the infusion, or to gain satisfactory assurance that the air subsequently admitted contained nothing of the kind. The only experiment in which these difficulties appear to have been fully overcome, is that in which the requisite apparatus was conceived by Professor Schulze of Berlin. He filled a glass flask half full of distilled water, in which were mixed various animal and vegetable substances: he then closed it with a good cork, through which were passed two glass tubes, bent at right angles, the whole being air-tight: it was next placed in a sand-bath, and heated until the water boiled violently. While the watery vapour was escaping by the glass tubes, the Professor fastened at each end an apparatus which chemists employ for collecting carbonic acid: that at the one end was filled with concentrated sulphuric acid, and the other with a solution of potash. By means of the boiling heat, it is to be presumed that every thing living and all germs in the flask or in the tubes were destroyed; whilst all access was cut off by the sulphuric acid on the one side, and by the potash on the other. The apparatus was then exposed to the influence of summer light and heat; at the same time there was placed near it an open vessel, with the same substances that had been introduced into the flask, and also after having subjected them to a boiling temperature. In order to renew constantly the air within the flask, the experimentor sucked with his mouth several times a day the open end of the apparatus, filled with the solution of potash, by which process the air entered his mouth from the flask after passing through the caustic liquid, and the atmospheric air from without entered the flask through the sulphuric acid. The air was of course not at all altered in its composition by passing through the sulphuric acid in the flask; but all the portions of living matter, or of matter capable of becoming animated, were taken up by the sulphuric acid and destroyed. From the 28th of May until the beginning of August, Professor Schulze continued uninterruptedly the renewal of the air in the flask, without being able, by the aid of the microscope, to discover any living animal or vegetable substance; although, during the whole of the time, observations were made almost daily on the edge of the liquid; and when, at last, the Professor separated the different parts of the apparatus, he could not find in the whole liquid the slightest trace of Infusoria or Confervæ, or of mould; but all three presented themselves in great abundance a few days after he had left the flask standing open. The vessel which he placed near the apparatus contained on the following day Vibriones and Monads, to which were soon added larger polygastric Infusoria, and afterwards Rotifera.* To the organisation of this higher form of Infusoria, which are always the last to appear in infusions, I now proceed.

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* CXXXV. vol. ii. p. 127.

The *Rotifera* are so called on account of the aggregation of their cilia into circular or semicircular groups upon lobes or processes of the head, which resemble rudiments of the ciliated tentacles of the higher or Ciliobrachiate Polypes.† By the vibration of these cilia, which occasions the appearance of little wheels in rapid motion, strong currents are produced in the surrounding water, and they thus serve as the instruments for locomotion and the prehension of food. The body in the Rotifera is more or less elongated or vermiform. It is provided, at its posterior extremity, with a pair of slender and pointed claspers, protected by a sheath, into which they can be retracted when not in use. These appendages are longer than the body in some species, as the *Notommata Tigris:* their sheath is much elongated and slightly annulated in the *Brachioni:* it is telescopiform in *Scaridium:* both claspers and sheath are wanting only in the *Anuræus.* The integument of the body is smooth, and never ciliated: although the parasitic jointed fibres of *Hygrocrocis,* which attach themselves sometimes to the integument of the larger species, as *Notommata centrura,* give it that appearance. In *Chætonotus* and *Philodina aculeata* the integument is beset with stiff bristles. The *Polyarthræ* have long jointed filaments, like the rays of a fish's fin, attached to the sides of the body; indicating the first rudiments of lateral members.

Not any of the species are known to secrete a silicious shell; but many of them are provided with a transparent gelatinous case, into which they can contract their bodies; thus offering another analogy to the Ciliobrachiate Polypes, and also to the bivalve-sheathed Entomostraca. The principal loricate genera are *Noteus, Anuræa, Bra-*

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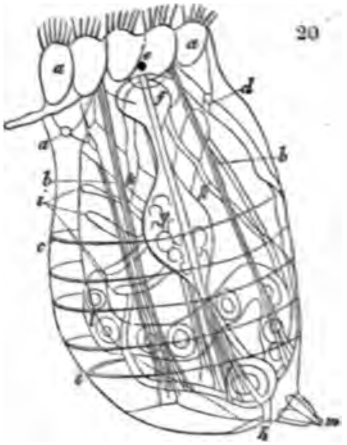
* XXXIV. vol. xxiii. p. 165. Pl. 1. fig. 2. gives a representation of the simple and effectual apparatus devised by Prof. Schulze. In a glass of water containing decaying *Spirogyræ* Cohn first observed *Paramæcium Aurelia,* which was followed in quick succession by Baker's *Proteus, Lacrimaria Proteus* or *Trachelocerca Olor, Chilodon cucullatus,* species of *Colpoda, Euplotes* of large size with green globules inside, and the colourless *Euplotes Charon.* All these succeeded each other in the course of three weeks. Then came the *Rotifers.*

† Ehrenberg remarks that the *Rotifera* are "Bryozoa without the power of propagating by gemmation." — XI. p. 384.

chionus, and *Pterodina*. In all the species the shell is a cylinder or case (*testula*), not a mere shield (*scutellum*). Horn-like processes project from the front margin of the firm shell in some species of *Brachionus*, and from both front and back margins in other species. In some *Notei* and *Anuræa* the shell is ornamented by large pentagonal or hexagonal groups of granules.

The cephalic cilia are aggregated into from two to five groups, upon lobes (*fig.* 20, *a*), or pedunculate discs, which in some species are developed into short tentacular processes, with a verticillate arrangement of cilia, as in *Floscularia* and *Stephanoceros* (*fig.* 22.). These lobes or processes Ehrenberg regards as muscular. The movements of the ciliated quasi-wheels are under the control of the will. They can be instantly arrested, the whole apparatus drawn out of sight, again protruded, and as instantly set in motion. The muscles which protrude and retract the ciliated lobes, which bend and modify the form of the body, and which throw out, attach, or heave in the anal anchors, are developed in the form of distinct narrow fibrous bands, which are transversely striated. The long and narrow longitudinal muscles which retract the head and shorten the whole body are sometimes in two pairs, one lateral and the other dorsal (*b*, *fig.* 20.). There are other mere filamentary longitudinal muscles, which are usually forked at their insertions. Very fine muscular threads are attached to the principal viscera, and keep them in their places. The antagonist transverse bands which diminish the breadth of the body and restore its length, are shown at *c c*, *fig.* 20. All these muscles are attached to an inner layer of the skin separable from the outer one.



Notommata.

With this advanced condition of the muscular system the parts of the nervous system now likewise become distinctly visible. Ehrenberg delineates a large cerebral ganglion, which in some species is of a trilobate form, in others (*fig.* 22, *b*) is double, and which is always in close connection with the coloured, generally red, ocellus or eyespeck (*fig.* 20, *e*, *fig.* 22, *a*). Some of the nervous filaments extend from this ganglion forwards to the muscular lobes supporting and moving the wheel-like cilia; other filaments of greater length stretch backwards into the cavity of the body, apparently attached to the ventral integument, on the outer side of the principal longitudinal retractor muscles. In *Notommata clavulata* Ehrenberg describes two radiated ganglions in the neck (*fig.* 20, *d*, *d*), superadded to the principal cerebral ganglion connected with the rotatory muscle, and other gangliform bodies on each side, developed upon the long abdominal nervous filaments. Besides these, other small enlargements are figured as ganglions upon the transverse bands or "vascular circles" of Ehrenberg, making altogether eight pairs of ganglions in this little animalcule, which measures one-eighth of a line in length. With regard to the ganglions on the so-called transverse vessels, both these and the vessels bear a striking analogy to those transverse muscles with a middle swelling, which Dr. Arthur Farre* has described and figured in his Ciliobrachiate Polypes. The most satisfactory indication of the nervous system in a Rotifer appears to be that given by Leydig in the *Lacinularia socialis*. It consists of two groups of four spindle-shaped nucleated cells, the extremities of which are attenuated and produced into fine (nervous) filaments. One group is situated between the pharynx and ingluvies; the other and more conspicuous group is placed in the base of the tail.†

The movements of the Rotifera are of a more varied character than those in the Polygastria; they sometimes dart swiftly forwards, at others glide leisurely along, or, anchoring themselves by their little terminal claspers, employ their ciliated paddle-wheels to create the currents which prove so fatal to the minuter race of Infusories. The *Philodina* creeps, like a leech, by the aid of a sucker at the mouth, and another at the end of the tail. When the *Rotifer* has attached itself to some fixed body by its hinder claspers, the vortices which it occasions in the water are so directed as to draw the smaller Infusoria and other particles of food towards the orifice of the infundibular mouth. In some species this cavity is so large as to allow of a considerable accumulation of food, as e.g., in the *Stephanoceros* (*fig.* 22, *c*). In *Lacinularia* a pair of bifid salivary glands open into it.

Having seized their prey, it is exposed in a second cavity or pharynx to the destructive action of a complicated dental apparatus (*fig.* 21, *f*). This consists of two horny jaws, acting horizontally upon a median piece, or anvil. The hard maxillæ are each bent upon themselves at a right, or, rather, acute angle; the transverse or dental part, which beats upon the surface of the anvil, being divided into two or more sharp spines. The muscles which work these dental hammers are disposed in four masses, and inserted into the longitudinal or posterior portion, which may be regarded as the rudimental jaw. The efficacy of these instruments in tearing to fragments the objects swallowed up may be easily discerned in the living animal through its transparent parietes.

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* XXXV. p. 394., pl. xxi., fig. 13.

† CLVII., p. 452. t. xvii.

The condition of the alimentary organs differs in the two sexes of the Rotifera. In the minute males there is a simple digestive sac, without intestine or anus; and those parts are absent, according to Gosse, in the female also of his *Asplanchna priodonta*.* In the females of all the species previously observed the alimentary canal is a more or less simple tube (*fig.* 20, *f*, *g*, *h*), commonly extending longitudinally through the well-developed abdominal cavity, to terminate by a cloacal outlet (*h*) at the hinder end of the body, generally above the base of the sheath of the claspers. In the loricate *Tubicolaris* and *Melicerta* the intestine is bent and the anus opens far forwards. The canal is sometimes wider, sometimes narrower, sometimes with (*Euchlanis*, *Brachionus*) and sometimes without (*Philodina*) a constriction indicative of the stomach: this cavity is usually well marked in *Notommata* (*fig.* 20, *g*): in *Rotifer* (*fig.* 21.) and *Ptygura* there is a distinct terminal dilation or rectum: sometimes the intestine is complicated with many cæca, as in *Diglena* and *Megalotrocha*. The lining membrane of the alimentary canal is beset with vibratile cilia, and the parietes consist of cells, with a colourless nucleus, and with a brown or green finely granular contents, which may elaborate a fluid analogous to bile. Most of the Rotifers (certain species of *Ichthydina* being exceptions) have, just behind the pharynx, or continued from the stomach, two large oval glandular sacs, rarely cylindrical or bifurcated, to which sometimes filamentary cæca are appended, as in *Enteroplea*. These secerning sacs (*fig.* 20, *i*) are also lined by a ciliated epithelium, and, from the colourless nature of their contents, are probably of the nature of pancreatic glands.

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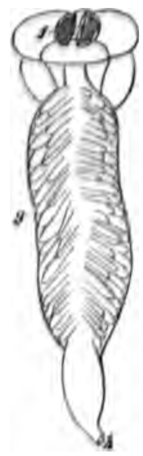

Al. canal. Rotifer.

Ehrenberg recognises a vascular system in the parallel transverse slender bands which surround the body; these are in close connection with the integument, and are more probably muscular.

In most Rotifers there extends down each side of the body a narrow band or tæniiform organ, containing a motionless vasiform canal. At the anterior part of the bands many short lateral vessels appear in some Rotifers to be in connection with the longitudinal canals : in Lacinularia these terminate here in a small convoluted knot. Rapidly vibrating or undulating ciliated tags are attached to different parts of the vasiform bands. The number of the vibratory tags varies not only in different species, but even in individuals of the same species. In general there are from two to three on each side, sometimes from five to eight, as in *Notommata copeus* and *N. syrinx;* and in the rare instance of *Notommata claviculata* as many as from thirty-six to forty-eight have been seen on each lateral band.

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* XXXVI. p. 20.

At the anal end of the abdomen the two lateral bands converge, and their longitudinal canals anastomose and open into a common contractile bladder, which expels its watery contents into the cloacal outlet. An aperture, sometimes supported on a special process at the fore-part of the trunk, probably admits the water into the abdomen, where it may be received into the freely suspended lateral canals, and expelled by the contractile bladder. This apparatus is viewed by Siebold with much probability, as subserving respiration. *Enteroplea, Hydatina,* and *Diglena,* have a simple anterior branchial aperture. *Rotifer, Philodina, Brachionus,* and some species of *Notommata,* have a branchial tube: *Tubicolaria* and *Melicerta* have a double branchial tube.

Groups and rows of minute granules may be observed in rapid molecular motion, immediately beneath the integument; and these are sometimes hurried along in currents, indicative of a circulatory movement.

The gelatinous cell or tube protecting the body in some Rotifera must be cited as one of the secretions in that class: the gland is situated at the base of the tail in Lacinularia, and its duct traverses that extensile part to terminate at its extremity. Many individuals of *Conochilus* and *Lacinularia* may be found in a conglomerate of such gelatinous shells, diverging from their fundus as from a centre. The individuals of *Tubicularia, Floscularia,* and *Stephanoceros* are protected in more elongated tube-shaped cells, which are commonly insulated. In *Melicerta* the protective tube is composed of multangular brown corpuscles, expelled from the cloacal opening, and compacted together.*

The Rotifera are of distinct sex; the females being larger than the males, and almost exclusively the subjects of scrutiny by the eminent micrographers to whom we are indebted for a knowledge of the anatomy of the class. Any other than female organs in these larger individuals has been ascribed to them only on the supposition

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* XXIV. p. 183.

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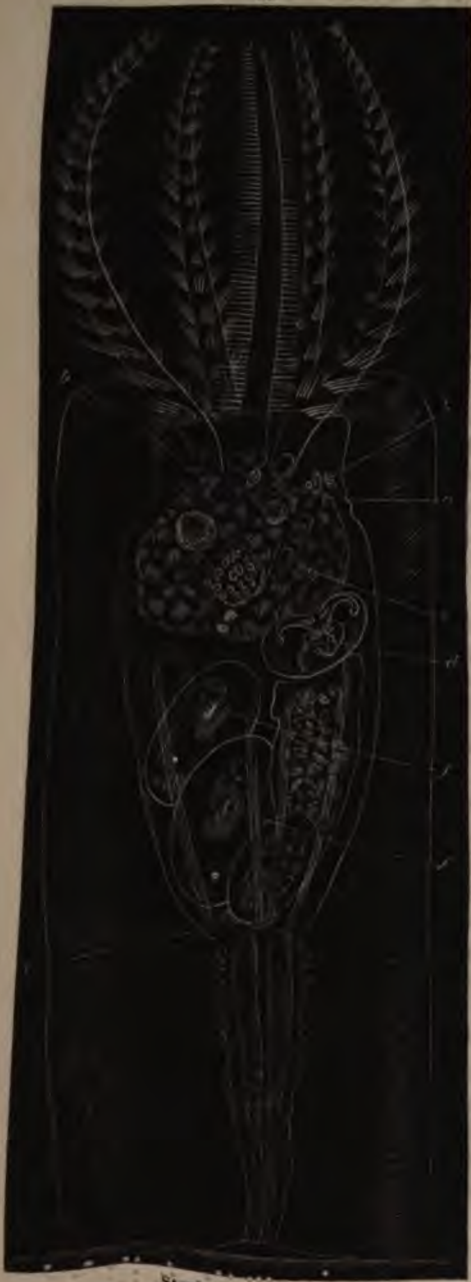

Stephanoceros Eichornii.

that part of the respiratory or aquigerous apparatus was the male organ. Most of the Rotifera are oviparous, the ova being large and few in number (*fig.* 22, *a.*): the *Philodinæ* are commonly viviparous. No species has yet been found to be parthenogenetic, either by way of spontaneous fission or gemmation.

The egg-forming organ consists of a simple wide sac, single in *Notommata* (*fig.* 20, *l.*), but more commonly divided into two cornua, the body terminating by a short contracted cervix, which communicates with the cloaca. The two other longer and more slender canals connected with the cloaca by the medium of the pulsatile sac, which are supposed by Ehrenberg to be the testes and seminal vesicle, are the parts already described as the respiratory system. In the first place Siebold has shown, that in the development of the Rotifera, the long and slender tubes appear and increase in the ratio of the growth of the intestinal organs and before the ovaria; secondly, they contain nothing but clear liquid; thirdly, the true nature of the pulsatile sac being determined in the Polygastria, we may infer that it has to do with the circulating and respiratory process in the Rotifera; and lastly, neither the pulsatile sac nor the slender lateral canals ever contain spermatozoa. The conclusion to which Siebold arrived, viz., that only female organs could be determined in the large and complex Rotifera, which had been examined by him and others, appeared, therefore, to be well-founded. At this stage of knowledge of the nature of the generation of Rotifera, the following observations were very timely and acceptable. Mr. Brightwell, who has paid much attention to the Infusoria, and has published a work on those found in the county of Norfolk, met with some small individuals of a species of *Notommata*, so different in character to the ordinary large female ones, to which they were often attached, as to give him the impression that they were the male individuals*; and in a letter which I have received from him he says: "I have lately repeatedly seen the male in connexion with the female; and it remains so for about seventy seconds." In these small individuals Mr. Dalrymple has discovered organs with abundant spermatozoa; but the rest of their structure is much more simple than that of the female: *e. g.* they have neither intestine nor anus. This may seem at first opposed to all ordinary analogies; but inferiority, not of size only, but in grade of organization, is no uncommon characteristic of the male in the invertebrate series. Nordmann discovered the male of the Lernæa to be a minute parasite upon the vulva of the female. Darwin has detected an analogous condition of the impregnating individual in certain Cirripedes; and the worm which Cuvier described under the name of the *Hectocolylus*, as the parasite of the Argonaut, appears from the observations of the accurate Kölliker, to be actually the male of that species.

In the *Notommata Syrinx* the male is about half the size of the female: it has a large round sperm-sac, or testis, at the lower end of its body, communicating by a short duct with a short penis or sperm-tube. The spermatozoa may be seen in active motion within the sperm-sac. On the 15th of June Mr. Brightwell † placed one of these males and six females in a small glass trough, and on the following day saw it attach itself to a female by his sperm-tube, remaining so attached twenty or thirty seconds: it afterwards repeated the act with four other females: the whole occupying a period of about fifteen minutes. Mr. Gosse ‡ has subsequently recognised similar males in the genus *Asplanchna;* and Dr. Leydig has described from one to four individuals in each colony of *Lacinulariæ* §, which exclusively develope spermatozoa: but he recognises in these the ovarium also, and believes them to be hermaphrodites, whilst the rest are females. There can be no doubt about the functions of the conspicuous ovarium in the latter, for the structure of the ovum can be discerned through its transparent walls (*fig.* 22. *f, f*): in the *Rotifer vulgaris*, the young may be seen to escape from the eggs in the uterus, and leave the empty shells behind them: they issue from the parent after intervals of from five minutes to an hour. The unimpregnated eggs are oval, with a firm colourless coat, containing a minutely granular, usually colourless, yolk, with a conspicuous germinal vesicle. In *Philodina roseola* and *Brachionus rubens* the yolk is of a reddish colour. In the tubicular Rotifera the eggs are generally deposited within the tube. In *Triarthra* and *Polyarthra* they remain attached to the cloacal opening. In some species two kinds of eggs are laid, one having two shells, and a later period of hatching, carrying the latent life of the germ through the winter, after the death of the parent.

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* XXXVII. p. 153. † XXXVII. p. 17. ‡ XXXVI. p. 22. § XXXV*. p. 471.

In the *Hydatina senta* Ehrenberg has carefully traced the formation of the ova. They are first manifested as clear spots or vesicles filled apparently with albumen. In two or three hours a dark speck is seen in the middle of the clear vesicle, which he compares with the yolk. In five or six hours the yolk fills the clear space and pushes it to one side, and in this state the ova are fecundated and excluded from the cloaca.

The change in the position of the clear spot is important, from its interesting analogy with the change in the position of the germinal vesicle in relation to the yolk of the rabbit's ovum, and with the altered position of the entire ovum in relation to the ovisac, preparatory to impregnation; both being, to use Ehrenberg's expression, "pushed to one side;" to that side, viz., which approximates the important vesicle whence all subsequent development radiates, to the surface which admits the fertilising principle. The result of this admission is seen in the commencement of the series of successive divisions of the yolk, the whole of which is acted upon by the previously dividing central hyaline nucleus, and is so converted into a 'germ-mass.' This process of 'total cleavage' of the impregnated egg-material has been described by Kölliker[*] in *Megalotrocha*, and by Leydig in *Lacinularia*[†], where the progression is 1, 2, 3, 4, 5, 6, 7, 8, &c., instead of 2, 4, 8, 16, 32, 64, as in the usual formation of the germ-mass. The further development of the Rotifera has been very well followed by Ehrenberg. He states, that in the ovum of the *Hydatina*, three hours after its exclusion, the clear spot (germinal vesicle) has disappeared, and the egg is occupied by the yolk, which is granular at one end and clear at the other. A dark spot

XXXVIII.

[†] XXXV*. p. 473. tf. xvii. f. 4.

then appeared in the middle of the ovum, which, *six* hours after exclusion, could be distinguished as the head, with the rudimental dental apparatus of the embryo. At the *eleventh* hour the wheel-like ciliated organs began to play, and the fœtus to move in the egg. At the *twelfth* hour the body was completely formed, and bent somewhat spirally, the bifurcated anal appendage being doubled backwards towards the head. The revolutions of the young Rotifer are now so powerful as to threaten every instant to burst the egg-shell, but they often continue two hours.

The average period of development of a young *Hydatina* under favourable circumstances is twenty-four hours; twelve within and twelve without the parent's body. When it proceeds more slowly, Ehrenberg recommends the liberal supply of the green monads, (*Chlamydomonas pulvisculus*, and *Euglena viridis*).

Ova deposited in the cold early days of winter remain undeveloped until spring, and are protected by their dense double shell. Ehrenberg watched during eighteen days successively an individual *Hydatina senta*, which was full-grown when singled out, and did not die of old age, which proves this species to live more than twenty days. Such an individual is capable of a four-fold propagation every twenty-four or thirty hours, bringing forth in this time four ova, which grow from the embryo to maturity, and exclude their fertile ova in the same period. The same individual, producing in ten days forty eggs, developed with the rapidity above cited,—this rate, raised to the tenth power, gives one million of individuals from one parent, on the eleventh day four millions, and on the twelfth day sixteen millions, and so on.

Although this rate of production from fertile ova is the greatest hitherto observed, far exceeding that in the class of insects, it is much inferior to the propagative power in the Polygastria. We saw that in the *Paramœcium aurelia*, which lives several days, a transverse fission took place, the individual becoming two, every twenty-four hours. It is affirmed also to propagate by ova, which are excluded, not singly, but in masses; which ova rapidly develope and repeat the acts of propagation; so that the possible increase in forty-eight hours is quite incalculable. Who can wonder that infusions should, with the brood of two or three days only, swarm with these animalcules.

All the ordinary Infusoria live through the winter beneath the ice. After having been once completely frozen, Ehrenberg found them dead when thawed. They, however, manifested considerable powers of resistance to this effect of extreme cold. Ehrenberg endeavoured to freeze some Infusoria in a watch-glass, and examined the clear ice in a cold room: he observed that those which appeared to be frozen and imbedded in the mass were actually inclosed in very minute vesicles in the ice. He conceives that they may remain torpid in this state through the winter, and revive when their little ice-houses have been melted away in spring.

Infusoria are destroyed generally by expanding and bursting, after a few minutes' subjection to the heat of boiling water.

In water subjected to a galvanic current strong enough to cause decomposition, the contained Infusoria are killed. When subjected to a weaker current, those only which came into its course were affected: some Rotifera were observed to be stunned only, and afterwards recovered; others were killed.

Tenacity of life is a very striking physiological character of the Infusoria.

The famous phenomena of the revival of Rotifera, after having been completely dried and apparently killed, certainly when reduced to the state of the most complete torpidity, were first observed by Leeuwenhoek in the year 1701.* The father of microscopical anatomy had been engaged in examining some specimens of *Rotifer vulgaris* with *Euglena sanguinea*, and had left the water in which they were contained, to evaporate. Two days afterwards, having added some rain-water, which he had previously boiled, within half an hour he saw a hundred of the Rotifera revived and moving about. A similar experiment was followed with the same result after a period of five months, during which period the Rotifera had remained in a state of complete desiccation and torpidity. These observations were repeated by Hill † and Baker.‡ You will find all the experiments that were recorded before the time of Haller accurately quoted in his great "Physiologia Corporis Humani," vol. viii. p. 111. Fontana § kept Rotifera two years and a half in dry sand, exposed to all the power of an Italian summer's sun: yet in two hours after the application of rain-water they recovered life and motion. Gözé, Corti, and Müller recorded similar experiments: but those performed by the celebrated Abbé Spallanzani are perhaps most generally known. He succeeded in reviving his Rotifers after four years' torpidity: he alternately dried and moistened the same animalcules twelve times with similar results, except that the number of the revivers was successively smaller; after the sixteenth moistening he failed to restore any of them to life. ||

* XXXIX. p. 386.

† XL. p. 11.

‡ XLI. Chapters iv. and vi.

§ XLII. tom. i. p. 87.

|| XLIII. vol. ii. p. 127.

One of the essential conditions of the revival of the Rotifers appeared to Spallanzani to be their burial in sand: the access of air seems prejudicial to their retention of vitality. Müller[*], the famous Danish observer of Infusoria, only succeeded in reviving them when they were surrounded by foreign particles, and defended from the air. Both Oken and Rudolphi[†] deny the revival of desiccated animals; but later observers have succeeded in reproducing the wonderful phenomena described by Spallanzani, especially Professor Schultze; and I myself witnessed at Freiburg, in 1838, the revival of the arachnidal *Arctiscon* which had been preserved in dry sand by the Professor upwards of four years.

Summary of the Classes, Orders, and Families of the "Infusoria" of Cuvier and Ehrenberg.

Class POLYGASTRIA.

Form, more or less that of a cell. ***Shell***, when present, siliceous or calcareous.

Motion, a few pedunculate, most are free and move by more or less generally diffused superficial vibratile cilia.

Digestion, by cavities in a soft parenchyme, without proper walls; the food taken either by superficial absorption or breach into the parenchyme, or by a mouth into a ciliated dilatable cavity.

Circulation, by one or more pulsating sacs.

Respiration, by rotating chlorophyl and by ciliated integument.

Generation, by spermatic nucleus governing partial or total fission of body, by gemmation, and by germ-cells, excluded as such (?), or developed within the body. No distinction of sex.

Order ASTOMA. Shell, when present, siliceous.

Families	*Monadina.*	Genera	*Monas, Microglena, Chilomonas, Bodo, Gregarina.*
	Astasiina.		*Amblyophys, Euglena, Chlorogonium.*
	Peridinina.		*Peridinium, Glenodinium.*
	Opalinina.		*Opalina.*
	Actinophryna.		*Actinophrys.*

Order STOMATODA. Shell, when present, siliceous.

Families	*Vorticellina.*	Genera	*Stentor, Trichodina, Vorticella, Epistylis, Carchesium.*
	Ophrydina.		*Vaginicola, Cathurnia.*
	Enchelia.		*Leucophrys, Prorodon.*

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[*] XLIV. p. 98.

[†] XLV. Bd. I. p. 285.

Trachelina.	***Glaucoma, Spirostomum, Trachelius, Loxodes, Chilodon, Phialina, Bursaria, Nassula.***
Kolpodina.	***Kolpoda, Paramæcium, Amphileptus.***
Oxytrichina.	***Oxytricha, Stylonychia, Urostyla.***
Euplotina.	***Euplotes, Himantophorus, Chlamidodon.***

Order RHIZOPODA.

Shell, calcareous, camerated.

Locomotion, by branched, retractile processes.

Tribe Monosomatia.

Family *Amœbina.* Genus *Amœba.*

Family *Arcellina.* Genera *Arcella, Difflugia, Gromia, Miliola, Euglypha, Trinema.*

Tribe Polysomatia.

Genera *Vorticialis, Geoponus, Nonionina.*

Class ROTIFERA. (Wheel-animalcules).

Form, Body oblong, with a tail or post-abdomen more or less jointed. Shell, when present, gelatinous.

Locomotion, by peculiar aggregates of vibratile cilia on the head.

Digestion, by an alimentary sac or canal, in an abdominal cavity.

Circulation, by a pulsatile sac, vessels, and sinuses.

Respiration, by an aquigerous apparatus with peculiar vibratile organs.

Generation, oviparous or ovoviviparous. Sexes distinct.

Family *Monotrocha.* (Single-wheeled). Genera *Ptygura, Ichthydium, Chætonotus, Œcistes, Conochilus.*

Family *Schizotrocha.* (Notch-wheeled). Genera *Megalotrocha, Tubicolaria, Stephanoceros, Lacinularia, Melicerta, Floscularia.*

Family *Polytrocha.* (Many-wheeled). Genera *Enteroplea, Hydatina, Notommata, Polyarthra, Triarthra, Euchlanis, Salpina.*

Family *Zygotrocha.* (Double-wheeled). Genera *Rotifer, Actinurus, Noteus, Philodina, Anuræa, Brachionus.*[*]

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[*] In this summary adopted, with slight modification, from Siebold (XXIV.), only those families and genera are cited which best serve as types of the organisation of the respective groups.

LECTURE IV.

ENTOZOA.

The ancient philosophers styled man the microcosm, fancifully conceiving him to resemble in miniature the macrocosm or great world.

Man's body is unquestionably a little world to many animals of much smaller size and lower grade of organisation, which are developed upon and within it, and exist altogether at the expense of its fluids and solids.

Not fewer than eighteen kinds of parasitic animals have been found to infest the internal cavities and tissues of the human body; and of these, at least fourteen are good and well established species of Entozoa.

Hippocrates and Aristotle had distinguished the human intestinal worms by the names of "Helminthes stronguloi" and "Helminthes plateiai;" but the study of these parasites in general has been reserved for recent times. Since Linnæus the stimulus which that great master gave to every branch of Natural History has been in no department more potent than in encouraging researches into the before neglected field of the Internal Animal Parasites.

To the labours of Goeze *, Zeder †, Bremser ‡, and, above all, to those of Rudolphi §, we are indebted for our knowledge of these animals as an extensive class, which Rudolphi has characterised, under the name of *Entozoa*, as white-blooded worms without respiratory organs, and (but less accurately) without nerves.

The number of these parasites may be conceived when it is stated that almost every known animal has its peculiar species, and generally more than one, sometimes as many as, or even more kinds than, infest the human body.

There are few common and positive organic characters which can be attributed to this very extensive and singular group of animals; they have generally a soft, absorbent, colourless integument, which in a few species is armed with spines. That the integument should be uniformly white or whitish might, *à priori*, have been expected of animals which are developed and exist in the dark recesses of other animal bodies. The mature ova are almost the only parts which naturally acquire a distinct colour; and the subtransparent body sometimes derives other tints from the accidental colour of the food. Excluded also by the nature of their abode from the immediate influence

* XLVIII. † XLIX. ‡ L. and LI. § XLVI. and XLVII.

of the atmosphere, no distinct respiratory organ could be expected to be developed in the *Entozoa;* but this negative character is common to them with most of the other "Zoophytes" of Cuvier. In animals surrounded by and having every part of their absorbent surface in contact with the secreted and vitalised juices of higher animals, one might likewise have anticipated little complexity and less variety of organisation. Yet the workmanship of the Divine Artificer is sufficiently complicated and marvellous in these outcasts, as they may be termed, of the Animal kingdom, to exhaust the utmost skill and patience of the anatomist in unravelling their structure, and the greatest acumen and judgment of the physiologist in determining the functions and analogies of the structures so discovered. What also is very remarkable, the gradations of organisation that are traceable in the internal parasites reach extremes as remote, and connect those animals by links as diversified, as in any of the other groups of Zoophytes, although these play their parts in the open and diversified field of Nature.

Beginning with the lowest link of the Entozoal chain, we have to commence with a condition of organisation more simple than is presented by the lowest Infusory or Polype. We end with a grade of organisation, which, whether it is to be referred to the radiated or articulated types, zoologists and anatomists are not yet unanimous.

Amongst the vermiform animals with colourless integument, colourless circulating juices and without respiratory organs, two leading differences of the digestive system have been recognised: in the one it is a tube with two apertures contained in a distinct abdominal cavity; in the other it is excavated or imbedded in the common parenchyme of the body, and has no anal outlet. The first condition characterises the *Vers Intestinaux Cavitaires* of Cuvier; the second the *Vers Intestinaux Parenchymateux* of the same naturalist.*

I have rendered the Cuvierian definitions of the two leading classes or groups of the Entozoa by the single-worded names "Cœlelmintha," and "Sterelmintha."

The Cœlelmintha include the *Linguatulæ* with the *Gordiacea* or 'hair-worms', and the cylindrical Entozoa or 'round worms' which form the order *Nematoidea* of Rudolphi.

This great entozoologist, who devoted the leisure of a long life to the successful study of the present uninviting class, divided the parenchymatous Entozoa, here associated in the class *Sterelmintha*, into four orders. The *Acanthocephala*, in which the head has a retractile proboscis armed with recurved spines, the body round and elongated, and the sexes in distinct individuals. The *Trematoda*, in which the head is unarmed and has a suctorious foramen, the body rounded or flattened, and generally one or more suctorious cavities for adhesion, and in which the organs of both sexes are in the same individual. The *Cestoidea*, in which the body is elongated, flattened, and generally articulated: the head, variously organised, generally provided with suctorious cavities, sometimes armed with a coronet of hooks, sometimes with four unarmed or uncinated tentacles: both kinds of generative organs are combined in the same individual. Lastly, the order of *Cystica*, in which the body is rounded or flattened, and terminates posteriorly in a cyst, which is sometimes common to many individuals: the head is provided with suctorious cavities, and with a circle of hooklets, or with four unarmed or uncinated tentacles. No distinct generative organs are developed in the cystic Entozoa, and there is good evidence that most, if not all, are larvæ of a higher order.

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* XII. tom. iv. p. 38.

The anatomy of the Entozoa is so distinct in each of these orders that I shall describe it successively in a few typical species, selecting more especially for demonstration those which infest the human body; and which chiefly concern the medical practitioner.

In this category the common pathological product called hydatid, and "Acephalocyst" by Laënnec, is by many received, and ought not, perhaps, in this place to be omitted. The acephalocyst (*fig.* 23, *b.*) consists of a sub-globular or oval vesicle filled with fluid. Sometimes suspended freely in the fluid of a cyst of the surrounding condensed cellular tissue (*a*); sometimes attached to such a cyst; developing smaller acephalocysts (*c*), which are discharged from the outer or the inner surface of the parent cyst. These acephalocysts vary from the size of a pea to that of a child's head. In the larger ones the wall of the cyst has a distinctly laminated texture. They are of a pearly whiteness, without fibrous structure, elastic, spurting out their fluid when punctured. Their tissue is composed chiefly of a substance closely analogous to albumen, but differing by its solubility in hydrochloric acid; and also of another peculiar substance analogous to mucus.* The fluid of the acephalocyst contains a small quantity of albumen with some salts, including muriate of soda, and a large proportion of gelatin.

23

Acephalocyst.

The tunic of the acephalocyst is usually studded with more or less numerous and minute globules of a clear substance (*c*), analogous to the "hyaline," whose remarkable properties in reproductive cells, Dr. Barry has demonstrated*, and from which the young acephalocysts are developed. No contractile property, save that of ordinary elasticity, has been observed in the coats of the acephalocyst; no other organisation than that above described; no other function than that of assimilation of the surrounding fluid by the general surface, and the development of new cells from the nuclei of hyaline. It stands on a still lower step in the series of organic structure than the *Protococcus* of the vegetable kingdom; for spontaneous fission has not been observed in any acephalocyst; and it ought, therefore, to be regarded rather as an abnormal organic cell, than as a species of animal, even of the simplest kind.

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* LII.

Yet these productions have not escaped the ingenuity and discriminative powers of the classifier. Of the numerous species, nominal or real, which are to be found in the works of naturalists and pathologists, I shall notice only a few: — 1st, the *Acephalocystis endogena* of Kuhn, likewise called *socialis, vel prolifera*, by Cruveilhier: the "Pill-box Hydatid" of Hunter. It is the kind most commonly developed in the human subject, and in which the fissiparous process takes place usually from the internal surface of the parent cyst, the progeny being sometimes successively included: and, 2dly, the *Acephalocystis exogena* of Kuhn, *eremita vel sterilis*, of Cruveilhier, which developes its progeny generally from the external surface, and is found in the ox and other domestic animals.

Mr. H. Goodsir, who has particularly studied the development of the acephalocysts †, has described three species of the genus, the specific characters being derived from the structure of the membrane from which they originate, and from the mode of growth and structure of the young.

In *Acephalocystis simplex* the membranes appear to be more or less inseparable, transparent, and the young vesicles are very few in number.

In *A. Monroi* the "germinal membrane" is divided by means of a fibrous tissue, into numerous compartments, each of which is occupied by a delicate transparent vesicle filled with cellular substance, of which the cells or division are very large. Each of these vesicles contains one or more small dark bodies — the young hydatids.

In *A. armatus* the young arise from the germinal membrane of the parent as very distinct small separate vesicles, which at first are quite transparent, but soon become opaque from the addition of young within them.

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* XXIX.

† LIII. p. 563.

A small transparent vesicle jutting out from the surface of the germinal membrane is the first vestige of a young hydatid, which speedily becomes opaque in consequence of young cells growing within it. This vesicle very soon separates, and then becomes what Mr. Goodsir terms a secondary hydatid. The young cells which were seen growing within it before its separation now also increase in size, and soon become parent cells, but do not separate from the germinal membrane of their parent until she escapes from the primitive hydatid. Thus there are four generations, the primitive hydatid still containing the three generations to which she had given birth.

If the primitive hydatid is buried so deeply in the tissues of the infested being as to prevent the escape of the secondary hydatids, with their two inclosed series of young, decomposition ensues, upon which they speedily disappear.

And now some may naturally be tempted to ask, having heard this description of a free and independent being, whose tissues are chemically proved to be of an animal nature, imbibing nourishment without vascular connexion with the cavity containing it, and reproducing its kind. How is an animal to be defined, if this be not one? The answer that the acephalocyst has no mouth, would not be regarded as satisfactory, after the recognition of the animality of the astomatous Polygastria: these, however, are locomotive and can propagate by spontaneous fission. But, definitions apart, our business is to discover to what organic thing the acephalocyst is most similar.

Almost all the animal tissues result from transformations of free cells, which grow by imbibition, and which develope their like from their nucleus of hyaline. It is to these primitive or fundamental forms of tissue that the acephalocyst bears the closest analogies in physical, chemical, and vital properties. When the infusorial monads are compared to such cells, and man's frame is said, by a figure of speech, to be made up of monads, the analogy is overstrained, because no mere organic cell has its cilia, its stomachs, its pulsatile sac, &c. So also it appears to me that the analogy has been equally overstrained, which makes the acephalocyst a kind of monad, or analogous species of animal. We may, with some truth, say that the human body is primarily composed or built up of hydatids; microscopical, indeed, and which, under natural and healthy conditions, are metamorphosed into cartilage, bone, nerve, muscular fibre, &c. When, instead of such change, the organic cells grow to dimensions which make them recognisable to the naked eye, such development of acephalocysts, as they are then called, is commonly connected in the human subject with an enfeeblement of the controlling plastic force, which, at some of the weaker points of the frame, seems unable to direct the metamorphosis of the primitive cells along the right road to the tissues they were destined to form, but causes them to retain, as it were, their embryo condition, and to grow by the imbibition of the surrounding fluid, and thus become the means of injuriously affecting or destroying the tissues which they should have supported and repaired. I regard the different acephalocysts, therefore, as merely so many forms or species of morbid or dropsical cells.

The conclusion to which the known phenomena of the parasitic gregarinæ lead is a different one; and to this much-mooted question I next pass.

In 1826, M. Léon Dufour* described and figured some minute entozooids, of very simple form and structure, which he discovered in the alimentary canal of several species of Coleoptera.

Subsequently, detecting them in great abundance in the chylific stomach of the earwig in the month of August, the same distinguished entomologist communicated a particular description of them to the 'Annales des Sciences Naturelles," 1828 †, proposing the name *Gregarina* for the genus; and he gives three figures of the species, under the name of *Gregarina ovalis*. It is half a line in length. One individual is characterised as having a spherical anterior segment. In a second this appears to have been lost, and is said to be replaced by a sort of skull-cap (calotte). The third, besides the constriction defining the anterior sphere, shows another constriction equally bisecting the trunk. Of this latter specimen Dufour remarks: — " Deux individus fixés bout à bout ou tête à queue, peut-être accouples:"—but either in the act of conjugation or of spontaneous fission. M. Dufour could detect nothing in the interior of these parasites except " des corpuscules arrondies." They were observed to vomit these " corpuscles " by the anterior end (probably after the fission).

Siebold, in 1837, not succeeding in observing any signs of voluntary movement in the *Gregarina*, rejected them at first from the kingdom of completely-formed animals, and supposed them to be eggs of insects.‡ Returning to the investigation, he soon, however, renounced his first opinion, and retained the genus, as unique and exceptional in its nature amongst the Entozoa. He observed, in some, a feeble contraction of the body, producing a vermiform figure. They consist of a very firm, smooth, completely-closed skin, which is highly elastic, and includes a milk-white, minutely granular mass, imbedded in which there is a clear cell, including smaller cells.

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* LIV. p. 44.

† XIII. p. 366.

‡ LV. p. 56.

Usually only two individuals were seen to be attached to one another. "Auch sah ich gewöhnlich nur *zwei* individuen aneinander kleben.*

Dufour had conjectured, that the genus *Gregarina* might belong to the *Trematoda.* Siebold, with better judgment, refers the genus to the order *Cystica.* He describes several species; and figures some in the state of either conjugation or of spontaneous transverse fission; he describes this as two complete individuals sticking together. Each shows the central multinucleate cell. Schleiden † has viewed these Gregarinæ as essentially a single organic cell, and would refer them to the lowest group of plants. And here, indeed, we have a good instance of the essential unity of the organic division of matter. It is only the power of self-contraction of tissue, and its solubility in acetic acid, which turn the scale in favour of the animality of the Gregarinæ; they have no mouth and no stomach, which have commonly been deemed the most constant organic characteristics of an animal.

Henle ‡ and others have questioned the title of the *Gregarina* to be regarded as an organic species or individual at all, or as any thing more than a monstrous cell: thus applying to it my idea propounded in 1843 of the true nature of the acephalocyst.

In 1848 Kölliker § published an elaborate memoir on the genus, in which good and sufficient grounds are given for concluding that the Gregarina not merely resembles, but actually is an animated being; it stands on the lowest step of the animal series, parallel with that of the single-celled species of the vegetable kingdom. The Gregarina consists, as Schleiden and others have well shown, of a cell-membrane, of the fluid and granular contents of the cell, and of the nucleus with (occasional) nucleoli. The nucleus is the hardest part, resisting pressure longest, like that of the Polygastrian. It divides, and its division is followed by spontaneous fission. Sometimes the establishment of the two centres of assimilative force separates the cell-contents into two groups, without the concomitant division of the cell-wall; but an inner partition-wall is developed. Stein believes that this is the result of the conjugation of two individuals. However this may be, another mode of propagation is then set up; the granules of the divided cell-contents, as if impregnated, develope cells, divide and subdivide, and are ultimately resolved into embryos having the form of Navicellæ; but without the siliceous shell. Kölliker is of opinion, from the frequent co-existence of these pseudo-navicellar capsules with the ordinary Gregarinæ and the identity of structure of the capsules, prior to the development of the pseudo-naviculæ; that this is one mode of propagation of the Gregarinæ, but the progress of the Navicella to the Gregarina has not been seen.

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* LV. p. 57. † LVI. p. 97. ‡ LVII. p. 369. § VII.

The cell-nucleus of the Gregarina answers to that of the Polygastria; the cell-membrane to the ciliated integument, and the granular contents to the more-specialised cells which surround the nucleus. The Gregarina may be regarded as a parasitic Monad, and the most simple of the animal kingdom. It differs from the single-celled plant by the contractility of its tissue, and the solubility of its cell-wall by acetic acid.

I next proceed to consider the internal parasites which present the characters assigned by Rudolphi to his Cystic Entozoa.

The name *Echinococcus* has been given to a cyst resembling the acephalocysts, in the absence of any external organised appendage, but differing in the structure of the innermost layer or "membrana propria," which is very thin and contains many minute clear calcareous corpuscles which on the application of a weak acid liberate bubbles of gas and disappear. The other tissues of this, which should be called the "echinococcocyst," consist, as in the acephalocyst, of coagulated albumen, the product probably of the adventitious cyst of the organ in which the echinococcocyst is imbedded. From the innermost or proper tissue of the echinococcocyst small pyriform buds project, in which are developed one or more minute vesicular organisms having a head armed with a circle of more or less bent spines (*fig.* 15, *a*), and in some species also four suckers (*ib. b*). These properly represent the genus *Echinococcus*. As their development advances, their nursing-cysts become pedunculate, and finally burst or break off, liberating the organisms which then float, or freely swim in the semi-albuminous fluid of the parent-cyst.* The tissue of the little echinococci is highly contractile, and the uncinated head can be retracted within the cavity of the body.

In the *Echinococcus Veterinorum*, the species which infests the common domestic animals, the oral spines, as retracted, offer a resemblance to the cylinder of teeth which characterises the *Nassula* (*fig.* 14.) and many other Polygastria. The tissue of the body presents a number of clear oval cells or spaces. On examining the fluid of an echinococcocyst from the abdomen of a recently-killed sow, I saw the young echinococci moving freely about in it: the anterior end of the body presented a trilobate depression produced by the retraction of the uncinated head, and at the opposite end there was, in some, a small orifice, "from which a granular and glairy substance was occasionally discharged."* The echinococci from a small musk-deer (*Tragulus*) closely resemble those of the hog. Each tooth or spine presents an elongated triangular form, a small process extending from the middle of its outer margin, probably for the attachment of the protractor fibres.

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* LVIII., LIX., LX., LXI.

24
Echinococcus hominis, magn.

The *Echinococci* of the human subject (*fig.* 24.), which have been accurately described by Professor Müller in a case where they were developed in the urinary bladder, and which have been carefully figured by Mr. Quekett in a case observed by Mr. Curling, where they were developed in the liver, present well developed suctorious cavities (*b*), external to the circle of teeth (*a*), and thus closely resembling the head of a Tænia, appended to a small cyst.

The hydatid developed in the substance of the brain of sheep and rabbits, called *Cœnurus cerebralis*, consists of a large cyst, with which many heads, like those of the Tæniæ, are in organic connection. These can be retracted within, or protruded without, the common cyst.

Our present knowledge of the generation of the *Cœnurus* is limited to one of the alternating modes, viz., the gemmation of the armed and suctorious vermiculi. The common or parent cyst is composed of two layers of substance,—the external one fibrous, or striated, in different directions; the internal of a delicate pulpy texture, locally thickened, and studded with minute clear cells. The gemmation of the vermiculi is not a process of continuous growth from the tunics of the parent cyst, but commences from an independent cell, situated between the layers, like the commencement of the bud from the hydra. Mr. Goodsir† has figured the progressive multiplication of cells from the primary one, closely analogous to the mode of establishment of the germ-mass from the primary-impregnated germ-cell in the ovum, until the cellular basis of the vermicule is established: it then pushes out before it the external fibrous layer of the mother-sac; and the organisation of the head is completed by the metamorphosis of the pre-developed cells. At this point, however, the generation by gemmation is arrested; the young individual is not cast off like the young Echinococcus or Hydra; its base continues in organic connection with the parent stock, and thus a compound animal, or aggregate of vermiculi results, analogous to the compound polypes, or as regards the general form of the community, to the Volvox globator.

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* LX. p. 118. Mr. Erasmus Wilson has noticed a similar fact in the Echinococcus hominis. LXI. p. 36. pl. 1. fig. 8. "Some of the granular contents of the animal expelled through the aperture left by the torn peduncle."

† LIII. p. 565. pl. xvi.

25

Cysticercus cellulosæ.

The genus *Cysticercus* is characterised by having only a single uncinated and suctorial head, connected by a neck or body, sometimes annulated, and of greater or less length, with the terminal cyst. Of this genus one species, *Cysticercus cellulosæ* (*fig.* 25.), is occasionally developed in the human subject. It has been met with in the eye, the brain, the substance of the heart, and the voluntary muscles of the body. The peculiar inflammation which it excites leads to the formation of a condensed bag of cellular tissue around it, which, in the muscular tissue, lengthens in the direction of the fibres, and so impresses an oval form upon the *Cysticercus:* but this form does not characterise the specimens developed in the softer tissue of the brain or liver. The *Cysticercus cellulosæ* is generally about half an inch in length.

The most common hydatid in the ox and other ruminants, is a large species of the present genus, called *Cysticercus tenuicollis*, which has been found weighing 25 drachms and containing 3 oz. of fluid. In these much-expanded *Cysticerci* muscular fibres are developed in different directions in the substance of the cyst, and produce lively contractions. The clear calcareous corpuscles which in *Cœnurus* and *Echinococcus* are scattered through the walls of the cyst immediately under the skin, in the *Cysticercus* are exclusively aggregated in the undistended part of the animal called the "neck." In the progress of the accumulation of the fluid in the main body, shreds of the tissue get occasionally detached from the inner surface of the dropsical cyst, and are occasionally seen hanging from the base of the neck and floating in the fluid.* In the oral circle of spines, these are arranged in a double row alternately long and short, and from twenty to thirty in number. The four suckers are imperforate. This well-armed head may serve to irritate the interior of the adventitious cyst and excite the secretion on which the parasite subsists.† All the *Cysticerci* manifest their affinity with the *Cestoidea* by the organisation of their head, and this is more strikingly illustrated by the length and segmentation of the body, with the comparatively small size of the cysts, in the *Cysticercus fasciolaris*, which is commonly found encysted in the liver of the rat and mouse. The question of the larval relation of all the above-described cystic entozoa to the *Cestoidea* will be entered upon after a description of the latter, to which I shall next proceed : limiting myself chiefly, in regard to the organisation of the Tapeworms, to the two species which infest the human intestines; namely, the *Tænia solium* and the *Bothriocephalus latus*, and which may be regarded as the types of the two leading genera of the order *Cestoidea*.

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* LXII. p. 205.

† LXI. p. 183.

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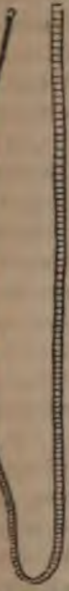

Head and neck, Tænia solium.

The *Tænia solium* is that which is most likely to fall under the notice of the British medical practitioner. It is the common species of tapeworm developed in the intestines of the natives of Great Britain; and it is almost equally peculiar to the Dutch and Germans. The Swiss and Russians are as exclusively infested by the *Bothriocephalus latus*. In the city of Dantzig, it has been remarked, that only the *Tænia solium* occurs; while at Königsberg, which borders upon Russia, the *Bothriocephalus latus* prevails. The inhabitants of the French provinces adjoining Switzerland are occasionally infested with both kinds of tapeworm. The natives of north Abyssinia are very subject to the *Tænia solium*, as are also the Hottentots of South Africa. Such facts as to the prevalent species of tapeworm in different parts of the world, if duly collected by medical travellers, would form a body of evidence not only of elminthological but of ethnological interest. In the *Bothriocephalus latus* of some parts of central Europe and of Switzerland we may perceive an indication of the course of those north-eastern hordes which contributed to the subversion of the Roman Empire; and the *Tænia solium* affords perhaps analogous evidence of the stream of population from the sources of the Nile southward to the Cape.

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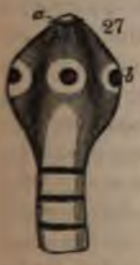

Tænia solium

The *Tænia solium* attains the length of ten feet and upwards: it has been observed to extend from the pylorus to within seven inches of the anus. Its breadth varies from one fourth of a line at its anterior part (*fig.* 26.), to three or four lines towards the posterior part of the body, which then again diminishes. The head is small, and generally hemispherical, broader than long. It commences by a central rostellum, which is surrounded by a double circle of small recurved hooks (*fig.* 27, *a*), occasionally shed in old individuals. Behind these are four suctorious cavities (*fig.* 27, *b*), by which the head is firmly attached to the intestinal membrane. The anterior segments are feebly represented by transverse rugæ; the succeeding ones are subquadrate, and as broad as long. They then become sensibly longer, narrower anteriorly, thicker and broader at the posterior margin, which slightly overlaps the succeeding joint. The last series of segments are sometimes twice or three times as long as they are small projections which are never observed in the Russian tapeworm. But the chief distinction between the *Bothriocephalus latus* and the *Tænia solium* is in the position of the generative orifices, which, in the *Tænia solium*, are placed near the middle of one of the margins of each joint, and are generally alternate (*fig.* 28, *a*, *a*).

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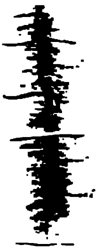

Tænia solium.

The integument of the Tænia is soft, like a mucous membrane; beneath it is a layer of delicate transverse muscular fibres, and a more easily recognisable stratum of longitudinal fibres. There must also be special muscles for the movements and retraction of the uncinated proboscis.

The condition of the nervous system is a matter of analogical conjecture. Its principal part must probably exist in, or near, the well-organised head, whence, as in the *Trematoda*, it may send backwards two delicate filaments.

The correspondence of the digestive system with that of many *Trematoda* is more strikingly shown, since it consists of long and slender canals continued lengthwise with transverse connecting channels in most species through the soft parenchyme. The mode of commencement of this system of canals appears to have been best seen by Siebold*, who describes and figures it in the larva of a tapeworm (*fig.* 30), as commencing by a circular canal around the opening of the fossa into which the uncinated proboscis is retracted. Four longitudinal vessels are continued from this circle, which bifurcate on arriving at each of the four suckers and re-unite below them, to be continued downwards as the main longitudinal vessels of the body (*fig.* 31, *a*, *a*). These contain a clear colourless liquid, and are readily seen in recent Tæniæ subjected to moderate pressure. This mode of investigation is better than that by injection, the natural extent of which cannot be defined by distinct walls of the spaces into which it may be driven. The transverse canals which connect the longitudinal ones in the *Tænia solium* are situated near the posterior margin of each segment. No other system of vessels can be detected in recent Tæniæ scrutinised in the way recommended. The longitudinal nutrient canals have no communication with the marginal pores: they equally exist in those Cestoidea which have no marginal pores, and the nutriment may be received by cutaneous absorption, the head being organised to serve chiefly as a hold-fast.

The tissue of the Tæniæ in which the alimentary canals are imbedded is beset with numerous minute nucleated cells. These, doubtless, take an important share, by their assimilative and reproductive powers, in the general nutrition of the body. The subcutaneous tissue is also characterised by the minute, clear and colourless calcareous bodies which are common in the cystic entozoa. There are also globules of oil.

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* LXIII. p. 206. pl. xiv.

The Tæniæ are androgynous, and each joint contains a complicated male and female apparatus equal to the production of thousands of impregnated ova. The ova are developed in a large, branched ovarium (*fig.* 28, *c*), occupying almost the whole space included by the nutrient canals, at least in the posterior segments, where it is very conspicuous from the amber colour of the more mature ova. The oviduct is continued from near the middle of the dendritic ovary to the marginal papilla, where it terminates by a small orifice, sometimes produced into a vulva, posterior to the pore of the male organs. The parts of the male apparatus which have at present been recognised consist of a small pyriform vesicle (*fig.* 28, *b*), situated near the middle of the posterior margin of the segment; this, however, is most probably only a seminal vesicle, and not the testis. The vas deferens is continued from the vesicle with slight undulations, to the middle of the segment, where it bends upon itself at a right angle, and terminates at the generative pore (*fig.* 28, *a*), from which the *lemniscus*, or rudimental penis, projects. The ova may be fecundated by intromission of the lemniscus into the vulva before they escape.

The segments containing the mature ova are most commonly detached and separately expelled. The development and metamorphoses of the embryo Tæniæ have not yet been completely traced out. But much has recently been done, especially by the sharp-sighted and clear-minded Siebold, to whose most valuable observations on this subject we shall return, after the description of the generative organs in the *Bothriocephalus latus.*

For a knowledge of the minute anatomy of this species of human tapeworm (*figs.* 29, and 30), we are indebted to the admirable skill and patience of Professor Eschricht, of Copenhagen, whose work* on the subject has received the prize of the Academy of Sciences, at Berlin. His observations were made on a specimen of the worm which, after various remedies, was dislodged from one of his patients.†

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* LXIV.

† In Denmark, as in Holland, the *Tænia solium* is the common tapeworm; but the case in question occurred in a female aged twenty-three, born at St. Petersburg, of Russian parents, who had spent almost all her childhood and youth at Copenhagen, with, however, occasional sojourns of three or four months' duration in Russia. The usual symptoms of tapeworm, with occasional ejection of fragments

The head and neck of this specimen are represented of the natural size in fig. 29, and magnified in fig. 30. Instead of the coronet of hooks and circle of suckers which characterise the head of the *Tænia solium*, it forms a simple, elongated, sub-compressed enlargement, with an anterior obtuse prominence, fig. 29, *a*, and two lateral sub-transparent parts separated by a middle opake tract. According to Bremser the margins are slightly depressed, forming what are termed the bothria or pits, fig. 31, *a*, *b*, whence the generic name of this tapeworm. There is no trace of joints for a short distance from the head: these are at first feebly marked; then the segments expand posteriorly, and slightly overlap the succeeding ones: their length nearly equals their breadth. At sixteen inches from the head a slight prominence in the middle line, the anterior part of the ventral surface of the segment, indicates the genital apertures. These become conspicuous in the posterior segments, and are two in number, situated on the same prominence (fig. 31).

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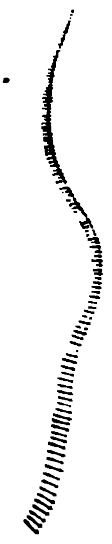

Head and neck, Bothr. latus.

The tegumentary and muscular systems appear to resemble closely those of the *Tænia solium*. Dr. Eschricht could not discern any trace of nerves. Of the nutrient system, he obtained evidence only of the submarginal longitudinal canals, by placing the recent segments in dilute acetic acid, he distinguished the contents of these canals, which were then manifest by their opacity and whiteness. How the nutritious fluid is absorbed by the *Bothriocephalus* Eschricht was unable to discern; he supposes, analogi-

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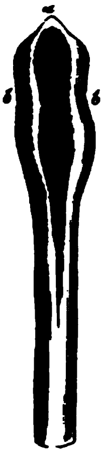
occurred in 1834. She had also [illegible] and other indications of a weakly constitution. Thrice, in that year, oil of turpentine with castor oil, and once some strong drastic pills and pomegranate root, were administered; and, with the exception of the last medicine, which produced no effect, each time from twelve to twenty feet of the worm were expelled, but without the head. In the spring of 1835 she was induced to try a remedy called "Schmidt's cure," which consists of strong coffee, and salt herring; and it was followed by the expulsion of a piece of the worm measuring ten yards, still without the head. She then paid a visit to Petersburg, and there parted with four or five pieces of the tapeworm measuring from two to four feet in length. She returned to Copenhagen in the winter of 1835, still suffering from her pertinacious parasite. Castor oil and turpentine were again administered on the 3rd of December, and procured the ejection of two pieces of the tapeworm, measuring together twelve feet in length, but without the head. Eighteen days afterwards, Nouffer's remedy, which consists of a preparation of fern seed, was resorted to, whereupon the remaining part of the worm, twenty feet in length, with the neck and head, came away, and all the symptoms of the malady disappeared, and had not returned in 1838, when this instructive case was recorded.

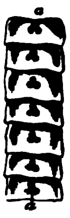
cally, by an anterior suctorious mouth, leading to a gullet, which bifurcates in the neck to form the two longitudinal canals. Eschricht could not detect the transverse anastomosing canals. We shall be justified, perhaps, by the analogy of a species of *Bothriocephalus* from the Python*, in which I succeeded in injecting with quicksilver both the longitudinal and transverse canals, in concluding that the anastomosing channels are present at the posterior margins of the segments in the *Bothriocephalus* of the human species. Siebold states that the annular vessel by which the nutrient canals commence in the rostellated *Tæniæ*, is not present in the genus *Bothriocephalus*, nor in the unarmed *Tænia rostellata* and *Caryophyllæus mutabilis:* in these tapeworms four longitudinal vessels when they approach the head begin to ramify and form there a rich network. This arrangement is more favourable to the idea of nutrition by cutaneous absorption, than by a hypothetical mouth and bifurcating gullet.

30



Bothr. latus.

31



Bothr. latus.

Innumerable and very minute nucleated cells are apparently disseminated through the tissue of the *Bothriocephalus.* Eschricht points out their analogy to the blood-cells in the lower animals, but could not perceive any ramified system of blood-vessels, superadded to the longitudinal canals.

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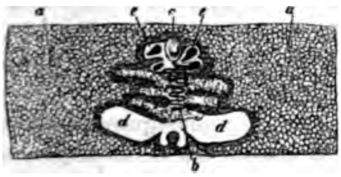

Bothr. latus.

At the deepest part of each segment there is a stratum of whitish granules or glands (*fig.* 32, *a*, *a*), composed of a cluster of minute blind sacculi, filled with opake fluid, each group or gland being suspended in a separate cell, the pedicle of which is, without doubt, the duct of the sacculated gland which Eschricht regards as a testis, and estimates at 400 in number at each joint. Their ducts unite to form a network, having the capsules of the gland in the interspaces. The vas deferens (*fig.* 32, *b*), is best seen on the dorsal aspect of the joint, along the middle of which it runs in close transverse folds, progressively increasing in breadth, until it terminates in a pyriform seminal receptacle or "bursa penis" (*fig.* 32, *c*). From this bursa a small lemniscus is protruded through the anterior of the two

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* Prep. No. 846. A.

generative pores, situated upon the eminence near the middle of the anterior part of the ventral surface of the segment.

The ovaria (*fig.* 32, *d*) are situated near the posterior margin of the segment. They consist of two large transversely oblong lobes, and a smaller median annular portion. They are composed of tubes in which the small germinal and vitelline rudiments of the ova are arranged in rows. The oviducts terminate in a long tubular uterus (*fig.* 32, *e*), which is considerably wider than the vas deferens, and advances forwards, making many transverse convolutions, the two last being wider than the rest, and extending on each side of the bursa penis. The ducts of a very complicated series of glands communicate with the uterus before its final termination at the vulva or pore, which is behind the male opening. The glands just alluded to form a stratum next beneath the skin at the sides of the joints. Eschricht calculates that there are 1200 of these glands in each joint. In the joints furthest from the head, containing the mature ova, these glands become filled with a thick yellow matter which they pour into a system of ramified ducts, which unite to discharge themselves in the dilated part of the uterus. Their office seems to be to cement together the ova in hard cylindrical masses by forming a crust around them, in which state they are found in the detached joints. This is the first example we have yet seen of nidamental glands, which we shall subsequently find to be a conspicuous part of the generative organs in many oviparous Invertebrata.

From this description it will be seen that the proportions and almost the forms of the ovarium and testis, are reversed in the *Bothriocephalus* and *Tænia:* the positions of the sexual outlets are unquestionably very different in the two genera. Both, however, agree in presenting the most extensive development and preponderance of the generative system that is known in the Animal Kingdom. In fact there is scarcely space left in the hinder joints of the tapeworms for the organs of any of the other systems.

The natural rate of life of a tapeworm, the consequences to the remaining adherent part of the repeated detachment of the ovigerous segments, the extent to which they are detached and subsequently renewed, have not yet been, nor are likely ever to be, the subjects of direct observation in these internal parasites of man.

Some highly interesting facts have, however, been made known by the same professor, to whom we are indebted for a knowledge of the anatomy of the *Bothriocephalus latus*, in the economy of another species of *Bothriocephalus* (*B. punctatus*) which is extremely common in the small sea-fish called *Cottus scorpius.*

During midsummer these tapeworms are fully developed, and their segments are laden with ova. They adhere by the fore part of the head to the mucous surfaces of the appendices pyloricæ, and cast off the ovigerous segments, sometimes in their whole length; so that headless tapeworms are found in the lower part of the intestine, whilst a number of heads without bodies may be observed adhering to the pyloric appendages between other tapeworms of very different lengths. The heads thus left behind generate a new series of perfect joints in the following way: the joint next the head is divided by a transverse fissure into two, each of which repeats the same process as soon as it is somewhat grown. Whilst the joints multiply in this way, they continue to increase in size, and so become removed from the head; but at a certain distance from the head, this mode of subdividing ceases, and the whole nutritive power is applied to the development of the organs of generation. During winter the *Bothriocephalus punctatus*, still adhering firmly to the mucous surface of the pyloric appendages, grows to its full length, the segments with the generative organs being formed; but no ova can be seen. These begin to appear at the commencement of spring in the posterior joints, and by degrees fill the uteri of all the joints, until they occupy those which are close to the head, when the separation from the head before described ensues, and this last-named member is left to repeat the important process. No single joint of a tapeworm can develope a head, and so form a new nutrient individual; the transverse fission relates only to the dissemination of the fertile ova. But the joints, so separated, may be regarded as "generative individuals," and those of the *Tænia solium* live and move about, and closely resemble *Distomata*. They may be seen in all grades of development, some as infants, others adolescent, and the terminal ones fully formed and pregnant.

The eggs of some Cestoidea have a single shell or tunic, which is colourless in *Tænia literata, T. Scolecina*, as well as in the genera *Caryophyllæus* and *Triænophorus;* but is of a brown colour in many species of *Bothriocephalus*. The round eggs of *Tænia amphitricha, T. serrata*, and *T. bifaria*, and the elliptic eggs of *T. angulata* and *T. villosa*, have two colourless tunics. In *Bothriocephalus proboscideus* and *Tænia porosa*, the eggs have three colourless tunics. In *Tænia solium*, the innermost of the three tunics is thick and becomes a yellowish brown in the ripe eggs. In *Tænia infundibuliformis* and *T. planiceps*, the outer tunic has two long pointed processes on each side: in *T. cyathiformis* it is provided with two round vesicular appendages. In *Tænia inflata*, the innermost of the three tunics is transversely elliptical, the middle tunic is produced into two long diverticula, and the outer tunic has two long lateral appendages. The eggs of *T. cucumerina* and *T. crateriformis* are collected in groups of from ten to twenty, in a common gelatinous nidamental capsule. In the eggs with a single brown shell the young are liberated by the fall of a kind of lid from one end.* In the other eggs the tunics dehisce irregularly to liberate the larva.

Wide and interesting questions on animal development are concerned in the solution of the narrower, but not less interesting ones, as to how and where the young of the impregnated ova of tapeworms are developed? In no instance have they been observed to be excluded in the intestines of the animal in which they were formed. The eggs are cast out with the excrement into the waters or on the surface of the earth.

Development of the cestoid embryo begins, however, as soon as the proper tunics of the ovum are formed, and it is commonly far advanced before the generative joints of the parent are expelled. The process has been studied by Siebold in the *Bothriocephalus proboscideus*, *B. crassicollis* and *B. infundibuliformis;* in *Tænia solium*, and in a score of other species of *Tænia*. In each case the embryo, presenting a rounded or oval shape, according to the shape of the egg, is characterised by having six spines or hooklets, retracted into the interior of the body: one middle pair lying in the axis of the body, the other two lateral pairs diverging and directed outwards. The embryos were found so armed even in the *Cestoidea*, which, when mature, are devoid of hooks and form the *Tæniæ inermes* of Rudolphi. In the *T. cyathiformis*, the two middle hooks are the largest and most bent. In *Tænia porosa*, one of the oblique lateral hooks is very thick, the other very slender. The young of the *Bothriocephalus proboscideus* present an ovate subdepressed form; and when they are two-thirds of a line in length, the bothria may be discerned at the larger end. The embryo of *Tænia ocellata*, when half a line in length, shows plainly, under the compressor, the four suckers.†

This discovery was soon confirmed by *Dujardin*, who gave a figure of the embryo of *Tænia cucumerina*, observed by him in the ova of the fully developed generative joints of that tapeworm from the intestines of a dog‡: and he has described the contractions of the body of the larva and the movements of the hooklets.

The earlier phases of development have been well traced by Kölliker, in both *Tænia* and *Bothriocephalus*.§ Development is first indicated by a clear place in the centre of the egg, which becomes more and more clear, larger, and nearer the surface of the yolk, where it is seen to be a nucleated cell. In this are developed two cells, which are liberated, and, repeating the process, form four cells; this cluster of germ-cells divides the more opaque yolk mechanically into two parts. The germ-cells become progressively smaller and more numerous, and the yolk becomes in the same ratio acted upon and diminished, until it is wholly absorbed and assimilated by the germ-cells, and the egg finally contains only the germ-mass so constituted; that is, consisting of the progeny of the primary germ-cell, developed and multiplied at the expense of the yolk, which is, therefore, exclusively a "germ-yolk" in the *Tæniæ*. The embryo above described is the result of the metamorphoses of certain cells of the germ-mass into its different tissues; viz. the skin, the proboscis, the six hooklets, and the suckers; the contained parenchyme consists of the remnant of the germ-mass comparatively little changed.

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* LX. p. 201., and XXIV. p. 148.

† LX. p. 202.

‡ LXV. p. 29. pl. i. fig. 10.

§ LXVI. p. 91.

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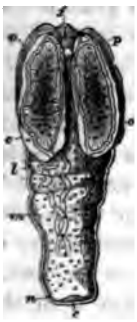

Larva of Tænia, magnified.

The next step in development has been observed by Siebold in the larvæ of *Tæniæ*, which have become parasitic in animals of quite distinct species from those in which the ova and ovigerous segments were formed.

In a species of slug (*Arion empiricorum*), e. g., Siebold observed minute white cysts projecting from the inner surface of the pulmonary sac. Each cyst contained a vermicule, with an uncinated and suctorial head retracted within the body. By regulated pressure the head was everted, and also the opposite end of the body, which had previously been intussuscepted, and the animalcule then presented the form given in *fig*. 33. Instead of six hooks, these were now arranged in a double row of ten in each. The contractile parenchyme of the unjointed body shows the vascular system above described, together with numerous minute cells and the clear calcareous corpuscles, but no trace of generative organs. These sexless larval cestoids are probably excluded from the ova of the tæniæ of some species of bird, voided with the excrement. Being hatched, they creep upon the body of the first slug that may crawl near them, and entering the open orifice of the pulmonary sac excite a certain inflammation by their hooks, become surrounded by an adventitious cyst, and attain that grade of development, as manifested by the number of the hooks, the suckers, and the length of the body, by which they differ from the larvæ as first formed in the egg of the tape-worm.* They have never been

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* With regard to the change from the six-uncinated embryo to the larvæ with the double crown of hooks, Stein states that the latter are a new formation which supersedes the embryonal armature of the proboscis. LXVII. p. 69.

found in a higher grade of development, or with sexual organs, in the intestines or other parts of the slug. Siebold therefore concludes that they may be restored to their native locality — the intestinal canal of a warm-blooded animal — by the slug being devoured by some mammal or bird, and that there they undergo their further and complete development; quitting their cysts, and forming their segments with the generative organs, which are detached by spontaneous fission.

This seems a bold hypothesis, and it would be a hazardous one if it rested on the mere facts of the resemblance of the vermicule (*fig.* 33.) in the pulmonic cysts of the slug to the embryo in the ovum of the Cestoidea. But the modifications of the hooks and suckers in some other vermicules, having the general character of cestoid larvæ, correspond so closely with peculiarities of the same parts in the tapeworms of animals feeding on those in which such larvæ are found encysted, as to add greatly to the probability of the migratory hypothesis. Siebold discovered vermicules, having the general character of cestoid larvæ, in cysts in the coats of the intestine, and free in the cavity of the intestine, of a cuttle fish (*Eledone moschata*). These vermicules had a large quadrangular head, divided by a slight constriction from the body, and bearing on its anterior flattened surface nine suckers, arranged as in *fig.* 35., the largest in the middle, the rest in four pairs, with the inner one largest in each. The parenchyme of the body of this vermicule presented the clear calcareous corpuscles characteristic of the cestoid tissue, together with the four longitudinal canals, as in *fig.* 33, *l;* with which evidence of its cestoid character, the next step was to examine what known species of mature or sexual cestoid presented the nearest resemblance to the peculiar cephalic organisation of the presumed larva. This Siebold found in the *Bothriocephalus auriculatus*, in which the four angles of the head are produced into distinct lobes, each bearing on its flattened anterior surface a pair of suckers corresponding in their inequality of size and relative position with those in the larvæ from the cuttle-fish; the large central sucker having disappeared in the course of the modification of the central interspace through the progressive development of the lobes (*fig.* 34.). That such change takes place in the condition of the peculiar head of the *B. auriculatus* is made probable by further changes observed in different individuals of that species. The suckers, for example, are seen in the younger specimens, and gradually disappear in the older ones. The animal

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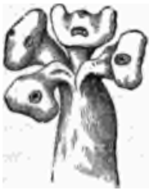

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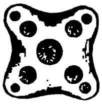

infested by the *B. auriculatus* is a carnivorous fish (*Mustelus vulgaris*), inhabiting the same sea as the *Eledone moschata*, and prone to devour that and other kinds of cuttle-fishes. The fertile ova of the *B. auriculatus* are discharged by thousands from the molluskivorous fish, and thousands of the larvæ doubtless perish. Some, however, gain an entry into the interior of the lower organised marine animals suited to their further development and encysted life; still fewer complete their vital career when the, to them, lucky accident occurs of the devouring of the mollusk containing them by the fish whose intestines form a suitable nidus for their ultimate transformation, and for the development and propagation by spontaneous fission of the generative segments.

Another cestoid larva found in cuttle-fishes and other marine invertebrata is characterised by its four lateral elliptical suckers, the tumid borders of which are facetted, or divided by many incisions. The *Bothriocephalus coronatus*, "bothriis tumidulis transversim costatis," of Rudolphi, presents the like peculiarities of its suckers, and it is found in the intestines of fishes that feed upon the invertebrates and smaller fishes in which the larva in question (*Scolex polymorphus*, Auct.*) is found.

To take a final instance, indicative of the migration of the cestoid larvæ, from land animals. The common tapeworm of the cat, *Tænia crassicollis*, is remarkable for the disproportionate size of the head, the short and thick neck, the position of the four suckers, and the shape and number of the hooklets of the uncinated proboscis: all these peculiarities are repeated in the larval form of tape-worm which is commonly developed in cysts of the liver of the mouse and rat, and which has already been described as the *Cysticercus fasciolaris*. The warm blood and high organisation of the small mammal in which that larva is developed may well be regarded as favouring a further advance of that development than takes place in the encysted cestoid larvæ found in the cold-blooded invertebrates; and accordingly we find, not only the uncinated proboscis and suckers of the tapeworm established, but also a lengthening and segmentation of the body, in the so-called *Cysticercus* of the rat, without, however, the development of the generative organs, and with a tendency to a dropsical accumulation of nutrient fluid in a few of the terminal joints.

All cestoid larvæ which find their early entrance into the soft tissues of mammalia seem to be subject to that accumulation. It is shown in a slight degree in the so-called *Cysticercus pisiformis* of the liver of the hare, which probably finds its full development as the *Tænia serrata* of the dog. But in many instances the dropsical enlargement of the encysted cestoid larva proceeds to such an extent as to make it highly improbable that they can carry out the future phases of their proper life-cycle.

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* LL t. xi. fig. 10. The cestoid larvæ, in their various grades of development, have served as the grounds of many nominal genera of entozoa; e.g. *Anthocephalus*, *Balanophorus*, *Bothriocephalus bicolor*, *Dibothriorhynchus*, *Floriceps*, *Gymnorhynchus*, *Hepatoxylon*, *Rhynchobothrium*, *Scolex*, *Tentacularia*, and *Tetrarhynchus*.

This we may conclude to be the case with the *Cysticercus cellulosæ* of the human subject, from the number of the adventitious cysts of that parasite which are found to contain the dead hydatids; these, moreover, have sometimes undergone a decomposition into an adipoceral and cretaceous mass, like a tubercle, but the true nature of which can frequently be demonstrated by the recognizable remains of the head, or of the hooklets of the abortive parasite.

In the encysted, probably cestoid, larvæ of the ruminants (*Cysticercus tenuicollis*, Auct.) the accumulation of the fluid proceeds to a greater extent; and in that to which the name *Echinococcus* has been given, it seems to be carried so far as to obliterate entirely both head and neck of the original larval form. The *Echinococcus* however, like the *Cœnurus*, retains so much of the original spermatic force in the germ-cells that remain unmetamorphosed in its parietes, as to set up a multiplication of its kind by gemmation. But the product never goes beyond the sexless vermicule with the uncinated and suctorial head, like that which is developed in the egg of the tapeworm. In the *Cœnurus*, these larvæ are retained, as we have seen, in organic connection with their parent-cyst, and bud out from her outer surface. In the *Echinococcus* they proceed from the inner surface of the cyst, and become free, reminding us of the development and accumulation of the navicellar larvæ, within the cyst-like body of the parent *Gregarina.*

The parthenogenetic mode of generation being the only one that the hydatid-like sexless progeny of the Cestoidea are able to manifest, the life-period of these dropsical larvæ, when not liberated, seems to be determined by the progressive accumulation of their parenchymal calcareous corpuscles, which have been absurdly described as their ova. The right recognition of the nature of the cystic entozoa of Rudolphi shows the futility of looking for normal organs of generation in any part of their structure.

The hypothesis of equivocal generation has been deemed to apply more strongly to the appearance of internal parasites in animal bodies than to the origin of animalcules in infusions. But if a tapeworm might be organised from a fortuitous concourse of organic particles, or by the metamorphoses of an organic cell in the animal it infests, why that immense complication and extent of the organs for the production of normal fertile ova?

"The division of the body into joints is intended," Professor Eschricht observes, "to produce a corresponding number of bunches of ova, just as the repeated ramification of plants is destined to provide space for the production of new bunches of seeds." The head of the tapeworm is fixed to the mucous surface, and thence it may derive the nutritive juices required for the whole organism, in a degree analogous to that in which the root procures the nourishment of the plant from the soil; and the analogy of the extent to which a plant is nourished by its leaf-pores may also be carried out by the extent to which the tapeworm is supplied by the absorbent action of its mucous integument. The ova having reached maturity, the joints rupture to liberate them; or the whole joint will be thrown off in the same way as the seeds of plants are freed, sometimes one by one, sometimes in masses, according to the particular manner of life assigned to every species of plant. "And is there any one," asks Dr. Eschricht, "who, upon the contemplation of this wonderful apparatus, and the extraordinary results of its agency, can for a moment imagine that it is without an object or an end?"

The geographical distribution of the human Cestoidea is, likewise, opposed to the doctrine of their spontaneous origin. The organic particles, or alimentary mucus of a Swiss and Dutchman, are not so distinct in their nature as to account for the difference in their tapeworms. Yet no Swiss that never left his native mountains ever had a *Tænia solium*, and no Dutchman, the constant resident of his swamps, ever had a *Bothriocephalus latus*. But a native of either of these countries may be infested by the tapeworm peculiar to another region, if he sojourn there, just as the English sailor may be attacked by the Guinea-worm, if he visits the tropical regions where that entozoon is common.

The great anatomist Soemmering suffered from a *Bothriocephalus latus*. Now he was a German; but it was ascertained that he paid occasional visits to a friend in Switzerland. There, doubtless, the larvæ of the parasitic worm was introduced into his body. The countless ova of the tæniæ, with their hard crusts or shells, and tenacity of latent life, are, doubtless, widely dispersed; the larvæ are early provided with express organs for attaching themselves to the animals and tissues suitable for their first phase of existence, and these nursing animals serve as food for the higher species destined, in their turn, to subserve the complete development of the migratory parasites.

LECTURE V.

ENTOZOA.

The essential anatomical character of the third order of Entozoa in the classification of Rudolphi may be represented by combining the head of an unarmed Tænia, with one of its joints, containing the fully developed androgynous organs. The digestive system being represented by simple canals, imbedded in the soft cellular parenchyme, and without anal outlet.

The *Trematoda* may be characterised as having a soft, flattened, rarely rounded, body, with an indistinct head, an unarmed mouth, and generally one or more suckers for adhesion in different parts of the body: the organs of both sexes are in the same individual.

Rudolphi was a pupil and ardent admirer of Linnæus, and adopted external and easily recognisable characters for the generic subdivisions of the Trematode order, the species of which he distributed according to the number and positions of the suctorious orifices and cavities. When there is a single one, it constitutes the genus *Monostoma:* when there are two, which are terminal or at opposite ends of the body, you have the character of the genus *Amphistoma:* when the posterior of the two suckers is not terminal, but on the inferior surface of the body, this constitutes the genus *Distoma:* three suctorious cavities characterise the genus *Tristoma;* five, the genus *Pentastoma*; and a greater number that called *Polystoma*. Subsequent anatomical investigations have led to the formation of other genera of *Trematoda*, and have likewise shown that those species which were grouped together by the external and artificial characters of the Rudolphian system, manifest differences of organisation, indicating, at least, the generic distinction of such species: nay, most of the *Pentastomata* of Rudolphi appertain to the Cœlelminthic class of Entozoa.

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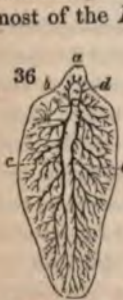

Dist. hepaticum, nat. size.

My illustrations of the anatomy of this order will be chiefly derived from the two species which infest the human subject; these are the *Distoma hepaticum* (*fig.* 36.), and the *Distoma lanceolatum* (*fig.* 37.). Both are peculiar to the biliary ducts and gall bladder, but may pass thence into the intestine. Both, likewise, are more commonly found in the ordinary domestic animals, as the sheep and ox, than in the human subject.

A full-grown *Distoma hepaticum* is of a flattened, ovate, or oblong-ovate form, broader and rounded anteriorly, attenuated posteriorly; from ten to sixteen lines in length, from four to seven in width: the broad end sends forward a sort of conical neck or head, convex above, flat below; one of the suckers (*a*) is at the extremity of this process, a little turned downwards, and is the true mouth; the other (*b*) is at the under part of the base of the neck, is imperforate, and serves merely as an organ of adhesion. Between these is a small depression (*d*) in which the genital pores are placed: not unfrequently the curved or spiral penis may be observed projecting from the anterior of these pores.

The body is of a whitish yellow colour, variegated near the margins by the yellow ova, and on the dorsal aspect by the brown colour of the double ramified alimentary tube. The integument is soft: traces of muscular fibres can hardly be discerned, except around the larger subventral sucker.

Dr. Mehlis*, who has given the best anatomical account of the human *Trematoda*, describes and figures the nervous system of the *Distoma hepaticum* as a delicate œsophageal filamentary ring, with a slight ganglionic enlargement on each side, from which minute fibres pass into the oral sphincter; and two large filaments pass backwards, one on each side, as far as the ventral sucker.

I have tested this description by a dissection of the largest known species of *Distoma*, the *Dist. clavatum*, whose anatomy I have described in the Zoological Transactions. You may distinctly perceive in this preparation† the œsophageal nervous circle, the small cephalic filaments, and the two widely separated nervous chords of the trunk. In this specimen also, you will see the integument raised as a distinct membrane from the outer transverse muscular fibres, and a portion of these is reflected from the inner longitudinal stratum. Feeble analogues of these parts of the muscular system are doubtless present in the smaller *Distomata* of the human subject. Pigment-specks, called "eye-specks," are present in the *Polystoma* of the urinary bladder of the toad and frog, as in the locomotive ciliated larva of most *Trematoda*. In the *Polystoma* six long muscles diverge from the hinder part of the body to have an expanded insertion into the convex sides of the six suckers.

The sole aperture of the alimentary system is that of the anterior pore, which is surrounded by the fibres of the suctorial organ. The alimentary canal in the *Distoma hepaticum* is continued from this pore for a very short distance as a single tube, and then bifurcates; the divisions (*fig.* 36. *c*, *c*) diverge to enclose the bursa penis and the ventral sucker, again approximate, and afterwards run parallel with each other, with a narrow interspace, along the middle of the body to the caudal extremity. At their first bend, each tube gives off three or four branches from its outer, but none from its inner side. The parallel tubes send off a few short and simple branches from the inner side, and many larger ramified branches from their outer sides, which terminate in blind extremities near the margin of the body.

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* LXVIII. p. 22. fig. 13.

† Prep. No. 1292 E.

These canals seem, at first sight, to be simply excavated in the substance of the body; but, attentively examined, they present a delicate proper tissue. They are usually filled with a brownish chyme, which appears to be mucus stained with cholesterine.

A more minute system of ramified tubes, which by some have been regarded as the nutrient vessels, commences or terminates by a small foramen at the caudal extremity of the body. The trunk of this system runs forwards with a slightly serpentine course, along the interspace of the forked alimentary canal, to the anterior part of the body, where it bifurcates, and terminates in many finely ramified branches: similar branches come off in pairs from, or terminate in, the main canal. These vessels seem to be an excretory rather than a nutrient system. They are beautifully figured by the ingenious anatomist Blanchard, who has succeeded in injecting them independently of the digestive canals.[*]

The vascular system of *Diplostoma volvens*, so beautifully illustrated by Nordmann [†], is the equivalent of the system of capillaries, described by Mehlis in the *Distoma hepaticum*; and the median trunk (*fig.* 38, *b*), which is compared by Nordmann to the dorsal aorta in the Anellides, must be the principal excretory conduit: it passes directly backwards to the terminal pore (*ib. h*), distinctly recognised by Nordmann in the *Diplostoma* as an excretory outlet: and he does not positively deny, what his figures indicate, its continuity with the straight duct terminating at that pore. In the *Dist. clavatum* I have shown that the excretory system is complicated by a large terminal receptacle or bladder, of which the hinder pore is the outlet.[‡]

The male organs of the *Distoma hepaticum* consist of the secerning seminal tubes, a vesicula seminalis, a penis, and its bursa: the convoluted tubuli testis equal the smallest branches of the alimentary canal in size; they occupy a great extent of the middle part of the body, are inextricably interwoven, are recognisable by their opake white colour, and terminate by two trunks in a common canal, which ends at the base of the receptaculum penis. This appendage is spirally disposed when flaccid, is tubular, and distinctly perforated at the apex.

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[*] LXIX. pl. 36. and LXX. (1820), p. 305. taf. iv. The idea of the nature and function of these vessels, given in my former edition, p. 57, has been adopted by the experienced Siebold, XXIV. p. 136. "So glaube ich gehört das Gefässnetz welches Bojanus aus *Distomum hepaticum* beschreibt jenem Excretionsorgans an."

[†] LXXI. p. 37. taf. iv. fig. 6.

[‡] LXXII. p. 41. fig. 18. *g*.

The ovaria occupy the whole margin of the body for a line in breadth: they consist of minute, branched tubes, in which the ova are developed, as in acini. The oviducts are close to the ventral integument, and terminate in a single large uterine canal, which is disposed in many convolutions between the subventral acetabulum and the bursa penis: it terminates by a vulva, or distinct pore, immediately behind the male bursa. The ovarian ova are colourless and pellucid, but become opaque as they approach the oviduct: having entered this tube they acquire a white glistening tunic, and afterwards a yellow colour, which becomes deeper as they approach the vulva.

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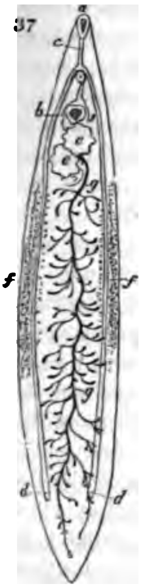

Dist. lanceolatum, magnified.

The *Distoma lanceolatum* (*fig.* 37.) has been regarded as the young of the *Distoma hepaticum;* but it is of a different form, has a different anatomical structure, particularly as regards the alimentary canal, and its title to rank as a distinct species is sufficiently vindicated by its power of developing fertile ova without changing its characteristic shape or increasing in size. It rarely equals five lines in length, but is more commonly three lines long; flat, lanceolate, more attenuated anteriorly, and with an obtuse caudal apex.

The suctorial pores are relatively larger than in the *D. hepaticum.* The anterior sucker (*a*) looks downwards, and is perforated in the centre by the mouth: the genital pores are half way between this and the hinder sucker (*b*). The transparency of the integument allows the internal parts to be readily discerned. The alimentary canal, commencing by a kind of pharynx, is continued as a very slender tube (*c*) to the bursa penis, where it bifurcates, each division (*d*) being continued without further ramification along the right and left sides of the body to the tail, where it ends in a blind extremity. The minuter excretory system of vessels has not been discerned in this small *Distoma.* The simplicity of its digestive apparatus makes the analogy very close between the *D. lanceolatum* and the *Tæniæ.*

In the interspace of the two digestive tubes four opake whitish spots are visible, of which the three anterior or larger ones (*e*) form the testes. Each transmits from its anterior margin a very minute duct, which, advancing forwards, unite in a common vas deferens, terminating in a small vesicle at the base of the penis, which is provided with its proper bursa. The ovaria (*f, f*) are two in number, of a milk-white colour, situated at the margins of the middle third of the body, exterior to the alimentary tube. They present a dendritic form, small branches being given off chiefly from their outer side. The oviducts run transversely to the middle line, and form there, by their convolutions, a fourth white opake body behind the testes. From this subspherical body the common uterine tube (*g*) is continued. This is a simple and ample canal, very long and tortuous, occupying all the posterior part of the interspace of the alimentary forks, thence continued forwards with decreasing convolutions, and terminating at the vulva.

The digestive system in the species of *Diplostoma*, a genus which has two ventral suckers (*fig.* 38, *b*, *c*), is as simple as in the *Dist. lanceolatum;* but the blind extremities (*f, f,*) of the two divisions of the alimentary cavity (*e, e*) are each lodged in a sac, *i*, which, from the milky character of its contents, has been termed the chyle-receptacle. It is supposed that the nutritious contents of the alimentary tubes exude through the parietes of their cœcal extremities into these receptacles. Two delicate vessels, *k, k*, are continued from the anterior and outer angle of each chyle-receptacle, which extend forwards to the anterior third of the body, and are there brought into communication by a transverse vessel, *l*, which extends across the dorsal aspect of the body. From the point of union of the transverse with the external lateral vessels, a single trunk is continued forwards on each side to the anterior angles of the body, *m, m*, where they bend inwards and unite in the middle line to form a median trunk, *n, n*, which is continued to the posterior extremity of the body, distributing or receiving branches on each side throughout its entire length, and apparently terminating at the posterior excretory pore, *h*. Through the connections of this system of vessels with the chyle-receptacles, the terminal pore might be regarded as an anal

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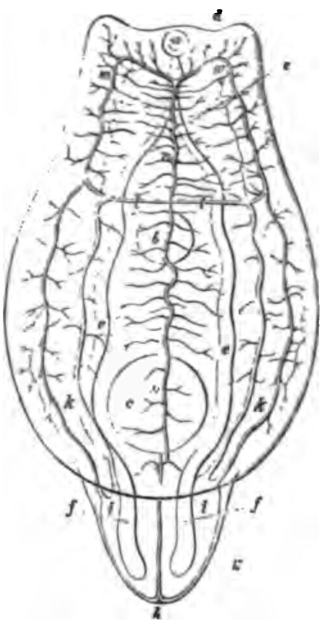

outlet to the digestive system, and the capillary vessels, extending from the chyle-receptacles to that pore, as a ramified form of intestine, fulfilling at the same time the office of lacteals, lymphatics, arteries, and veins; but an excretory function is doubtless the chief one of this ramified system of vessels.

In *Monostoma mutabile* the two digestive canals bend towards, and anastomose with, each other at the hinder end of the body. In *Aspidogaster* the digestive canal is continued backwards, without dividing, and ends by a cul-de-sac. A similar simple blind tube is continued from the mouth of *Gasterostoma*, which, as that name implies, is situated at the middle of the abdomen. In *Distoma chilostoma* and other species from the abdomen of Neuropterous insects, two short blind tubes diverge right and left from the gullet. The ramified type of the alimentary canal, exhibited by *Dist. hepaticum*, is repeated in *Octobothrium palmatum*, *O. Merlangi*, *Polystoma appendiculatum*, *Tristoma elongatum*, and in the genus *Diporpa**, which, in the state of conjugation†, represents that apparently most extraordinary form of the present order, called by Nordmann, its discoverer, *Diplozoon paradoxum*. In this Trematode, as well as in some others, e. g. *Distoma echinatum*, *Aspidogaster conchicola*, certain parts of the vessels show a ciliated inner surface, or special ciliated processes extending therefrom, which actively vibrate, and may relate to a respiratory process.

The posterior contractile sac, already referred to in the *Distoma clavatum*, is present under certain modifications in many *Trematoda*. It is simple in *Monostoma Faba*, *Distoma cirrigerum* and *Gasterostoma fimbriatum*; is bifurcate in *Distoma clavigerum*, *D. tereticolle*, *D. variegatum*, and in many *Monostomata*, in which the two blind ends of the sac reach almost to the head. If I have been right in regarding the so-called "vascular system" of *Dist. hepaticum* as homologous with this sac and its prolongations, we have, then, in that species, a third (ramified) form of the excretory organ. An intermediate modification is presented in the *Amphistoma conicum*. The contents of the excretory sac consist usually of a colourless fluid containing many granules and vesicles: but sometimes it is filled by clear calcareous corpuscles like those found in the parenchyme of the cestoid worms and their cystic larvæ. These substances are excreted by the terminal pore. In the above-cited lower organised Sterelmintha the lime-corpuscles remain aggregated beneath the skin.

The genus *Planaria* of Müller is now known to include many generic types of fresh-water vermiform animals, not internal parasites, yet closely allied, by their organisation, to the order *Trematoda*.

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* LXXIII. p. 316. pl. 8. f. c. 200.

† LXXIV. p. 63.

duct, which, advancing forwards, unite in a common vas deferens, terminating in a small vesicle at the base of the penis, which is provided with its proper bursa. The ovaria (*f*, *f*) are two in number, of a milk white colour, situated at the margins of the middle third of the body, exterior to the alimentary tube. They present a dendritic form, small branches being given off chiefly from their outer side. The oviducts run transversely to the middle line, and form there, by their convolutions, a fourth white opake body behind the testes. From this subspherical body the common uterine tube (*g*) is continued. This is a simple and ample canal, very long and tortuous, occupying all the posterior part of the interspace of the alimentary forks, thence continued forwards with decreasing convolutions, and terminating at the vulva.

The digestive system in the species of *Diplostoma*, a genus which has two ventral suckers (fig. [illegible]), is as simple as in the *Dist.* [illegible]: but the blind extremities (*d*, *d*) of the two divisions of the alimentary cavity (*e*, *e*) are each enlarged into a sac, *i*, which, from the milky character of its contents, has been termed the chyle-receptacle. It is supposed that the nutritious contents of the alimentary tubes exude through the parietes of their [illegible] into these receptacles. Two delicate vessels, *k*, *k*, are continued from the anterior and [illegible] of each chyle-receptacle, [illegible] forwards to the anterior [illegible] of the body, and are there brought into communication by a [illegible] which extends [illegible] of the body. [illegible] of the [illegible] external lateral [illegible] is continued [illegible] to the anterior [illegible] *n*, *n*, where they [illegible] form a median [illegible] extremity of the body. [illegible] throughout its [illegible] excretory [illegible] with the [illegible] might be regarded as an anal [illegible] the eversion of the intromittent organ and the exclusion of the eggs. Two accessory vesicles communicate with the common generative passage, one of which is probably a sperm-reservoir, the other a nidamental sac; the ova of some species are attached by short filaments, the secretion of such a sac, to the stems of aquatic plants.

The chief modifications of the generative organ in the parasitic *Trematoda* will be understood by reference to the description of them already given in the two species infesting the human subject. A third modification may be briefly noticed as it exists in the *Distoma perlatum*, discovered by Nordmann in the intestines of the Tench. It is illustrated in the subjoined cut from the magnified figure, given in that excellent observer's beautiful work.[*] In *fig.* 39. *i*, is the vagina expanding into *h*, the glandular uterus, or nidamental organ; *l*, *m*, are the two testes, beset internally with small spines; *n*, the prominent tube, by which the ova are excluded; *o* is the termination of the oviduct in the cavity of the testis *m*; *p*, *p*, are the convolutions of the oviduct, laden with ova, received by *r*, the short tubes leading from the ovaria *q*, *q*, which are widely extended through the parenchyme of the sides of the body.

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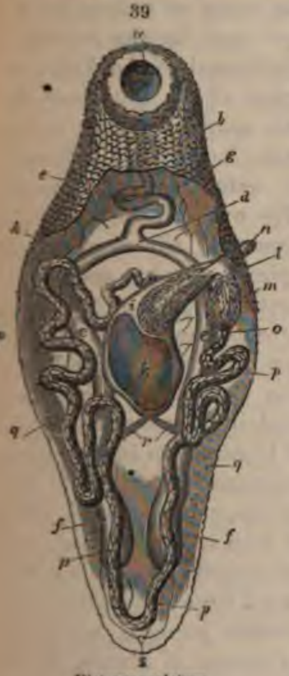

Distoma perlatum.

As to the development of the *Trematoda*. When the Entozoologist contemplated the *Tænia* fixed to the intestine, with its uncinated and suctorious head buried in the mucous membrane, rooted to the spot, and imbibing nourishment like a plant; — when he saw the sluggish *Distoma* adhering by its sucker to the serous membrane of a closed internal cavity; — he naturally asked himself how they got there? And finding no obvious solution to the difficulty of the transit on the part of such animals, he was driven to the hypothesis of spontaneous generation to solve the difficulty. It is no wonder that Rudolphi and Bremser, who studied the Entozoa rather as Naturalists than Physiologists, should have been led to apply to them the easy explanation which Aristotle had given for the coming into being of all kinds of Vermes, become aggregated in the centre of the locomotive larva, which may be compared to the locomotive germ or zoospore of an alga or sponge. It is, in fact, a single-celled animal with a ciliated as well as a contractile cell-wall.

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[*] LXXII. p. 91. t. ix. fig. 4.

In a short time after it has escaped from the ovum the ciliated integument ruptures and its contents disappear, with the exception of the concentrated nuclear matter, which is left clear and distinct, and of a definite form. A spontaneous movement is observed in this body: it grows, and now a granular structure may be seen in it under a high magnifying power. Before its escape it seems to be a compact structureless mass; but afterwards numerous points or centres of independent force begin to operate, and give rise to multitudinous minute granules or nuclei, and it takes on a structure comparable to that of the Gregarina. Now, what is the condition of this second phase or form in the metagenetic progress of the entozoon?

It will be observed that the embryo of the monostoma, when it quits the ovum, is not like the chick; the primary germ-cells have not been converted into numerous and diversified tissues and organs; the great majority of them remain unchanged, and without exhaustion of the spermatic force. This force would seem to be concentrated in the clear nucleus, which expands to constitute the smooth-skinned Gregariniform worm. In this, as in the pseudo-navicellar capsules, numerous unchanged germ-cells or nuclei set up as many centres of development, from each of which a cercariform embryo results. In this process many of the germ-cells and nuclei are metamorphosed into organs, and a corresponding proportion of the spermatic force is exhausted. What remains serves to govern the subsequent developments, which result in the change of the individual Cercaria into a Monostoma or a Distoma; this is a "metamorphosis;" but the antecedent phases should rather be called a "metagenesis,"* and the conditions essential to that act are the retention of a due proportion of the primitive germ-mass unchanged, and with its primarily received spermatic force unexhausted.

Some of the Trematode Entozoa are remarkable on account of the places they are found in; as, for instance, the *Diplostoma volvens*, which infests the interior of the eye of the perch and other fishes. The pupa of this species has been found in the eye of the perch, coiled up, adhering to the inner side of the cornea, and then there has been observed an oblique line, or trace in the cornea, which shows how the cercariform larva bored its way through to get there. But frequently it does not get so far, and one finds such pupæ in cases like a watch-glass adhering to the skin or conjunctiva outside the eye. It is probable that different stages of the *Diplostoma volvens* have been de-

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* XXX.

and a *Distoma;* many individuals under the two latter forms being developed out of one impregnated ovum.*

Professor Siebold † has traced the metamorphoses of another species of Trematoda up to a certain point, the rest being made intelligible by the analogy of those of the snail. He found that certain waterfowl were, at particular seasons, infested with a small kind of fluke-worm, the *Monostoma mutabile*. Rudolphi and others had described them in the alimentary canal; Siebold likewise found them in the air-cells of the abdomen. He discovered this species to be viviparous, and observed the act of bringing forth, when the *Monostoma* was placed in cold or luke-warm water. The ova and embryo are developed as in the tænia. The first germ-cell appears in the midst of a thick granular germ-yolk; it multiplies, and its progeny, as they become smaller and more numerous, break through or divide the yolk, and finally consume it. The embryos escape from the vulva, close to the penis, and swim briskly, while the egg-shells fall to the bottom. Sometimes an egg was excluded, containing the embryo, which soon escaped. It is 1-9th of a line in length, of a long oval shape, with a truncated head and a rounded tail-end. On the upper part of the head are a pair of square dark pigment-spots, which reminded Siebold of the eyes of the cercaria. In the terms of the "alternate generation" theory the gregariniform being is the grand-nurse "gross-amme;" the ciliated monadiform larva is the great-grand-nurse. This is an exposition of the main facts in figurative language, but is not an explanation of them. What we require are the conditions of structure, which give or admit of the power of procreation without the coitus or act of impregnation in the procreating animal. They appear to be these; and they are revealed by examining the structure of the entozoon in question in the several stages of its genetic cycle, comparing them with each other and with the changes operated in the ovum by the reception therein of the spermatic principle.

In the development of the monadiform larva of the monostoma or distoma, either the vitelline membrane is metamorphosed into the ciliated skin of the larva, or this is formed by the metamorphosis and coalescence of the peripheral layer of the germ-mass. But, admitting the latter process, no other parts of that impregnated germ-mass are changed excepting those which form the external contractile and ciliated integument; there is no mouth, no stomach or other internal organs, and no members; the only change which has taken place in the impregnated germ-cells is rather a kind of change of the relative position of the essential spermatic or clear nuclear matter, which has muscular investment.* The mouth is a minute pore, situated on the extremity of the uncinated proboscis: it leads to two long cylindrical canals excavated in the soft parenchyme adherent to the muscular tunic, and are continued to the posterior extremity of the body, sending off throughout their course a number of fine transverse vessels which anastomose together. Two short, slender, cylindrical, or flattened bodies, are continued backwards from the sheath of the proboscis, and are freely suspended in the anterior part of the general cavity: they are called *lemnisci.* These bodies contain a fine granular parenchyme, and are richly supplied by a reticulate system of vessels, which communicate with those of the lateral canals, where the pedicles of the lemnisci are attached to the sheath of the proboscis. This apparatus, which in its form resembles a vascular system†, is the only part of the organisation that appears to relate to the nutrition of the worm. Hunter has left some remarkable instances of the boring powers of the *Echinorhynchi:* in No. 289, he shows the *Echinorhynchus porrigens*, attached to a portion of the intestine of the Piked Whale (*Balæna Boops*, LINN.). The worm has perforated the intestine, and has formed in its parietes a tortuous passage; the head having penetrated the mucous and muscular coats, and returned again through the latter, into the intervening cellular coat. The sides of the canal are composed of thickened and condensed cellular membrane, and in the enlarged cavity which contains the head there is a quantity of curdled matter, which appears to be lymph thrown out in consequence of the irritation. The main body of the parasite continued to float in the chyle and mucus of the intestine, which may be received into the fine vascular network of the skin by cutaneous absorption: the uncinated proboscis serving chiefly as an anchor or hold-fast. Hunter has placed this preparation in his series of "*Parts analogous to Teeth in Invertebrate Animals.*"

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* XCIII. p. 52.

† XCIV. p. 321.

The male organs consist of two fusiform testes, attached to each other and to the proboscis by a suspensory band; two varicose vasa deferentia, which unite together to terminate in a single vesicula seminalis; and a long intromittent organ provided with a bursa occupying the posterior extremity of the body, and having a special muscular apparatus for the retraction and extrusion of the contained organ. Beneath the testes there are from one (*Ech. claviceps*) to six pyriform bodies, which secrete a minutely granular matter, and whose ducts, in the latter member, which is most common, unite into two tubes that terminate in the bursa penis. The secretion of the proper the size of the female. The generative organs in this sex consist of two ovaries and one oviduct. The ovaries are long and wide cylindrical bodies, which of themselves occupy almost the whole cavity of testes is characterised by the numerous actively moving capillary spermatozoa. The yellowish wax-like cement which is often found sticking round the vulva of the female is probably the secretion of the accessory pyriform bodies. The male echinorhyncus is generally half the body, extending from the proboscis to the tail, and appearing to float freely in the fluid of the general cavity: they contain a granulo-cellular mass in which the ova are developed. When ripe, the ovaria dehisce and the ova fall into the cavity of the body. The oviduct is supported by a suspensory ligament answering to that in the male, and opens freely, like the fallopian tube, by a bell-shaped mouth, into the cavity. The ova are taken up by it, and conveyed to a short muscular uterus, and are excluded by a vulva at the hinder end of the body. When first liberated, the ova have a single tunic, and consist of the vitellus in a minutely granular, and sometimes vesicular mass, but without a trace of germinal vesicle. In the uterus the ova have acquired two additional coats.

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* XXIV. p. 125.

† LXXVII. tab. 2. f. 10., tab. 3. figs. 10. 12. 21. LXXIX. figs. 1. 8.

LECTURE VI.

ENTOZOA.

The four orders of the class *Entozoa* which have already been described, are less natural than the order *Nematoidea*, which will chiefly occupy our attention in the present lecture. The *Cystica*, *Cestoidea*, *Trematoda*, and *Acanthocephala*, are far from being respectively equivalent to the order *Nematoidea*, either as regards grade, difference, or circumscription of organic characters. The transition from the cystic to the tænioid Entozoa was so obvious and close, by the *Cysticercus fasciolaris*, for example, that they were combined in the same order "*Tænioidea*," in the "Règne Animal." Cuvier, however, did not abolish the order *Cestoidea*, but separated the jointless *Ligulæ*, in which the head has neither suckers, bothria, nor uncinated proboscis, from the other Tænioids, in order to form it. It is hardly possible, however, to separate from the Tænioids of Cuvier, the intestinal *Ligulæ* of water-fowl, in which traces of both bothria and generative organs begin to manifest themselves. And Rudolphi's hypothesis that such *Ligulæ* might be the more simple *Ligulæ* of fishes that had been transferred to the warmer intestines of the birds preying upon such fishes, there to undergo their final metamorphoses, has been established by later observations, which have also shown that the *Cystica* of Rudolphi are for the most part, if not all, larval forms, in a normal or abnormal state, of the *Cestoidea*. With respect to the higher organised *Cestoidea* of Rudolphi, it has been already observed that they very closely resemble a composite form of *Trematoda*. The extensive and natural group formed by the two heterogeneous orders of "Sterelmintha" form, therefore, the equivalent of the *Nematoidea*. The *Acanthocephala* constitute a more limited yet natural order: and the *Linguatulæ* (*Pentastoma* of Rudolphi) are the type of an analogous circumscribed group (*Onchophora*) with a higher type of organisation, which entitles them to rank in the class *Cœlelmintha*. This class includes all the cavitary intestinal worms of Cuvier, with the exception of the "Vers ridigules" of Lamarck, or Epizoa, which are proved by their metamorphoses to belong to the siphonostomous Crustaceans.

The order *Nematoidea*, which forms the chief part of the class *Cœlelmintha*, must chiefly interest the physician, since it includes the principal internal parasites of the human subject: viz. *Trichina spiralis*, *Filaria medinensis*, *Filaria oculi*, *Filaria bronchialis*, *Trichocephalus dispar*, *Spiroptera hominis*, *Strongylus gigas*, *Ascaris lumbricoides*, and *Ascaris* or *Oxyurus vermicularis*. To the order *Nematoidea*, repeated examinations, since my first observation of the minute *Trichina spiralis* *, induce me to refer that singular microscopic parasite (*fig.* 40.). I have satisfied myself of the accuracy of Dr. Farre's † and Dr. Henle's ‡ description of the distinct canal in the cavity of the body. In a specimen of *Trichina* now under the microscope, a loop of this canal may be seen protruding through a rupture of the abdominal wall. The vermicule is always contained in a cyst. The occurrence of these cysts in vast numbers in the muscular tissue was first made known in an interesting case published by Mr. Hilton §: and many others have since been recorded.

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Cysts of Trichina spiralis. Nat. size.

The cysts are very readily detected by gently compressing a thin slice of the infected muscle between two pieces of glass and applying a magnifying power of an inch focus. They are of an elliptical figure, with the extremities more or less attenuated, often unequally elongated, and always more opake than the body or intermediate part of the cyst, which is, in general, sufficiently transparent to show that it contains a minute coiled-up worm (*fig.* 41.). The usual size of the cyst is $\frac{1}{50}$th of an inch in the long diameter, and $\frac{1}{100}$th of an inch across their middle part. The cysts are arranged with their long axis parallel to the course of the muscular fibres (*fig.* 40.), which probably results

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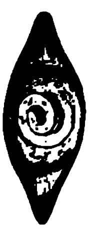

Trichina spiralis, and its cyst, magn.

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* LXXX. vol. i. p. 315. † LXXX*. ‡ LXXXI. p. 528. § LXXXII.

from their yielding to the pressure of the contained worm, and becoming elongated at the two points where the separation of the muscular fasciculi most readily takes place, and offers least resistance.

The innermost layer of the cyst can sometimes be detached entire, like a distinct cyst, from the outer portion, and its contour is generally well marked when seen by transmitted light. By cutting off the extremity of the cyst, which may be done with a cataract needle or fine knife, and gently pressing on the opposite extremity, the Trichina and the granular secretion with which it is surrounded, will escape; and it frequently starts out as soon as the cyst is opened.

When first extracted, the Trichina is usually disposed in two or two and a half spiral coils; when straightened out it measures $\frac{1}{30}$th of an inch in length and $\frac{1}{700}$th of an inch in diameter, and now requires for its satisfactory examination a magnifying power of at least 200 linear admeasurement.

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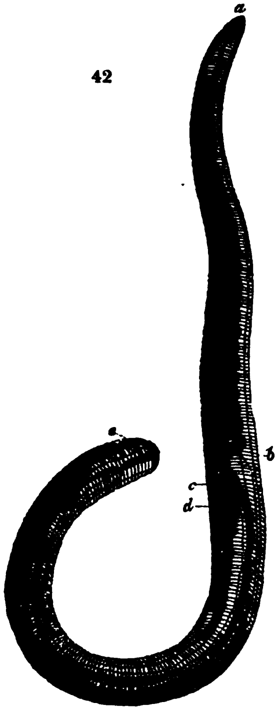

Trichina spiralis, magnified.

The worm (*fig.* 42.) is cylindrical and filiform, minutely annulated, terminating obtusely at both extremities, which are of unequal sizes; tapering towards one end for about one-fourth part of its length, but continuing of uniform diameter from that point to the opposite extremity which is trilabiate.

The free canal, which commences or is attached by a capillary tube or filament, at the small end (*fig.* 42. *a.*), rapidly widens and presents a saccular form through one half of its course: it is then continued of a more slender and equable form to the great end. At the junction of the saccular with the slender part, *b*, of the canal there are, according to Luschka*, two small cœca. Near these is the blind end, of a second canal which contains the small cluster of minute dark granules†, and is continued to the trilabiate end of the body; Luschka‡ believes both tubes to terminate here in a blind end.

The worm has no organic connection with the cyst: sometimes two *Trichinæ*, rarely three, occur in the same cyst.

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* LXXXIII. p. 77. taf. iii. fig. 5. *c c.*

† LXXXIV. p. 63., and LXXXV.

‡ This author seems only to have read LXXX., and to have been unacquainted with the additional observations on the "Anatomy of the Trichina," in LXXXIV.

The Medina or Guinea-worm (*Filaria medinensis*, Gmel.) is developed in the subcutaneous cellular texture, generally in the lower extremities, especially the feet, sometimes in the scrotum, and also, but very rarely, beneath the tunica conjunctiva of the eye. It appears to be endemic in the tropical regions of Asia and Africa.

The length of this worm varies from six inches to two, eight, or twelve feet; its thickness is from half to two-thirds of a line; it is of a whitish colour in general, but sometimes of a dark brown hue. The body is round and sub-equal, a little attenuated towards the anterior extremity. In a recent specimen of small size, we have observed that the orbicular mouth was surrounded by three slightly raised swellings, which were continued a little way along the body and gradually lost; the body is traversed by two longitudinal lines corresponding to the intervals of the two well-marked fasciculi of longitudinal muscular fibres. The caudal extremity of the male is obtuse, and emits a single spiculum; in the female it is acute, and suddenly inflected.

The *Filaria medinensis*, as has just been observed, is occasionally located in the close vicinity of the organ of vision; but another much smaller species of the same genus of Nematoidea, infests the cavity of the eye-ball itself.

The *Filaria oculi humani* was detected by Nordmann in the liquor Morgagni of the capsule of a crystalline lens of a man who had undergone the operation of extraction for cataract under the hands of the Baron von Gräfe. In this instance the capsule of the lens had been extracted entire, and upon a careful examination half an hour after extraction there were observed in the fluid above mentioned two minute and delicate *Filariæ* coiled up in the form of ring. One of these worms, when observed microscopically, presented a rupture in the middle of its body, probably occasioned by the extracting needle, from which rupture the intestinal canal was protruding; the other was entire, and measured three-fourths of a line in length; it presented a simple mouth without any apparent papillæ, such as are observed to characterise the large *Filaria* which infests the eye of the horse, and through the transparent integument could be seen a straight intestinal canal, surrounded by convolutions of the oviducts, and terminating at an incurved anal extremity.

The third species of *Filaria* enumerated among the *Entozoa hominis* is the *Filaria bronchialis*; it is described by Treutler* as occurring in the enlarged bronchial glands of a man: the length of this worm is about an inch; it is slender, subattenuated anteriorly, and emitting the male spiculum from an incurved obtuse anal extremity.

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* LXXXVI. p. 10.

The next human entozoon of the Nematoid order belongs to the genus *Trichocephalus*, which, like *Filaria*, is characterised by an orbicular mouth, but differs from it in the capillary tenuity of the anterior part of the body, and in the form of the sheath or preputial covering of the male spiculum. The species in question, the *Trichocephalus dispar* Rud. (*fig.* 43.) is of small size, and the male is rather less than the female. It occurs most commonly in the cæcum and colon, more rarely in the small intestines. Occasionally it is found loose in the abdominal cavity, having perforated the coats of the intestine. The capillary portion of this species makes about two-thirds of its entire length; it is transversely striated, and contains a straight intestinal canal; the head (*a*) is acute, with a small simple terminal mouth. The thick part of the body is spirally convoluted on the same plane, and exhibits more plainly the dilated intestine; it terminates in an obtuse anal extremity, from the inner side of which project the intromittent spiculum and its sheath.

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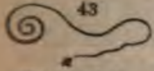

Trichocephalus dispar. Nat. size.

The species called *Spiroptera Hominis* was founded by Rudolphi on some small nematoid worms expelled, with many larger elongated bodies of a solid texture, and with granular corpuscles, from the urinary bladder of a woman, whose case has been described by Mr. Lawrence in the Medico-chirurgical Transactions.* The *Spiroptera* varies from eight to ten lines in length; the head is truncate, the mouth orbicular, with one or two papillæ, the body is attenuated at both extremities; the tail in the female, thicker, and with a short obtuse apex; that of the male more slender, and emitting a small tubulus; a dermal aliform production near the same extremity determined the worms in question to belong to the genus *Spiroptera*.†

The most formidable, but, happily, the rarest of the nematoid parasites of man, the *Strongylus gigas*, also infests the urinary system, but is developed in the kidney, where it has attained the length of three feet, with a diameter of half an inch; occasioning suppuration and destructive absorption of that important glandular organ.

The male (*fig.* 44.) of this species is less than the female, and is slightly attenuated at both extremities. The head (*a*) is obtuse, the mouth orbicular, and surrounded by six hemispherical papillæ; the body is slightly marked with circular striæ, and with two longitudinal impressions; the tail is incurved in the male, and terminated by a dilated pouch or bursa, from the base of which the single intromittent spiculum (*g*) projects. In the female the caudal extremity is less attenuated and straighter, with the anus a little below the apex; the vulva is situated at a short distance from the anterior extremity.

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* Vol. ii. p. 385.

† XLVII. p. 251.

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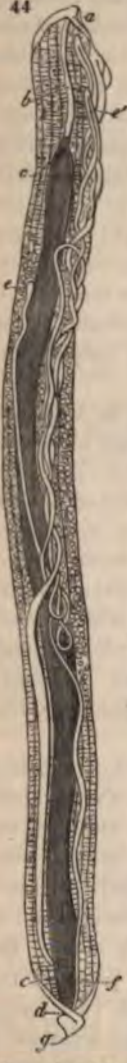

Strongylus gigas.
Nat. size.

The *Strongylus gigas* is not confined to the human subject, but more frequently infests the kidney of the dog, wolf, otter, racoon, glutton, horse, and ox. It is generally of a dark blood-colour, which seems to be owing to the nature of its food, which is derived from the vessels of the kidney; as, where suppuration has taken place, the worm has been found of a whitish hue.

The round-worm (*Ascaris lumbricoides* Linn.) (*fig.* 46.) is perhaps the most anciently known* and common of the human Entozoa, and is that which has been subjected to the most repeated, minute, and successful anatomical examinations. It is found in the intestines of man, the hog, and the ox. In the human subject the round worms are much more common in children than in adults, and are extremely rare in aged persons. They are most obnoxious to individuals of the lymphatic temperament, and such as use gross and indigestible food, or who inhabit low and damp localities. They generally occur in the small intestines.

The body is round, elastic, with a smooth shining surface, of a whitish or yellowish colour; attenuated towards both extremities, but chiefly towards the anterior one (*fig.* 46, *a*), which commences abruptly by three tubercles, which surround the mouth, and characterise the genus. The posterior extremity (*d*) terminates in an obtuse end, at the apex of which a small black point may frequently be observed. In the female this extremity is straighter and thicker than in the male, in which it is terminated more acutely and abruptly and is curved towards the ventral side of the body. The anus is situated in both sexes close to the extremity of the tail, in form like a transverse fissure. In the female the body generally presents a constriction at the junction of the anterior with the middle third, in which the vulva (*e*) is situated.

The body of the *Ascaris lumbricoides* is transversely furrowed with numerous very fine striæ, and is marked with four longitudinal equidistant lines extending from the head to the tail. These lines are independent of the exterior envelope, which simply covers them; two are lateral, and are larger than the others, which are dorsal and ventral. The lateral lines commence on each side of the mouth, but, from their extreme fineness, can with difficulty be perceived; they slightly enlarge as they pass downwards to about one-third of a line in diameter in large specimens, and then gradually diminish to the sides of the caudal extremity. They are occasionally of a red colour, and denote the situation of the principal vessels of the body. The dorsal and abdominal longitudinal lines are less marked than the preceding, and by no means widen in the same proportion at the middle of the body. They correspond to the two nervous chords, hereafter to be described.

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* It is the ελμινς στρογγυλος of Hippocrates.

The last species of human Entozoon which remains to be noticed is the *Ascaris vermicularis* (*fig.* 47.), a small worm, also noticed by Hippocrates under the name of ασκαρις, and claiming the attention of all physicians since his time as one of the most troublesome parasites of children, and occasionally of adults, in both of whom it infests the larger intestines, especially the rectum. The size of the male *Ascaris vermicularis* is two or three lines; that of the female is five lines.

The integument in the nematoid parasites of the human subject, and in almost all the order, is more or less smooth: it consists of a thin compact epidermis, and of a fibrous corium firmly attached to the outer transverse muscular fibres. The epiderm is homogeneous; *i. e.* it does not show the nucleated cellular structure. It is impressed by minute, close-set, transverse indentations, which, in some of the Nematoidea of the lower animals (*Strongylus annulatus*, e. g.) are so deep as to give an annulate character to the integument; and in the *Ascaris nigrovenosa* the sides of the body appear thereby to be fringed. Lobes, or aliform processes of the integument, characterise certain genera and species; e. g. the alæ of *Spiroptera*, the finely-striated "moustaches" on the head of the *Ascaris mystax*, the serrated membrane supported on tubercles near the tail of the same worm. The corium consists of decussating fibres. The entire integument is highly absorbent; and, after death, endosmose will go on to such an extent as sometimes to cause the parietes of the body, if immersed in fluid, to burst. The epiderm is developed in the *Strongylus horridus* of the water hen, into four longitudinal rows of reflected hooklets; and similar spines are arranged in circular groups upon the anterior part of the *Gnathostoma spinigerum*.

M. Cloquet, in his elaborate monograph on the *Ascaris lumbri-*

[illegible] correctly states that the exterior layers of muscular fibres are transverse, and the internal longitudinal; the latter are arranged in [illegible] fasciculi in four groups. In this large specimen of the *Strongylus gigas*, which I have inserted for the muscular system, you will perceive that a very thin layer of transverse fibres adheres strongly to the integument, the fibres being embedded in delicate furrows on the internal surface of the skin. Within this layer, and adhering to it, but less firmly than the transverse fibres do to the integument, there is a thick layer of longitudinal fasciculi, which are a little separated from one another, and distributed, not in eight distinct series, but pretty equally over the whole internal circumference of the body. Each fasciculus is seen, under a high magnifying power, to be composed of many very fine fibres, but these do not present the transverse striæ which are visible by the same power in the voluntary muscular fibres of the higher animals. They anastomose in many parts. The inner surface of the stratum of longitudinal fibres is covered with a soft tissue composed of small obtuse processes, filled with a pulpy substance and containing innumerable pellucid globules.

In the muscles [illegible] species of the *Linguatula tænioides*, the fibres show the transverse striæ.

[illegible] development of the muscular system [illegible] more obvious elimination of the nervous filaments, which, in the *Linguatulæ*, radiate from a distinct [illegible] ganglion. Amongst the Nematoidea the great *Stron-* [illegible] demonstration of the nervous [illegible] the beginning of the [illegible] from its inferior part, and [illegible] middle of the ventral aspect to [illegible] a slight swelling is formed [illegible] is surrounded by a loop [illegible] chord commenced.† The [illegible] to the longitudinal muscular [illegible] them with the naked eye by [illegible] which it sends off on each [illegible] off at pretty regular intervals [illegible] round to nearly the opposite [illegible] chord in the female of the [illegible] of the vulva, and does not [illegible] of the vagina, as Cloquet [illegible] to do in the *Ascaris lum-* [illegible] dorsal nervous chord has been [illegible] from the œsophageal ring, down the middle line of that aspect of the body corresponding to the ventral chord on the opposite aspect.*

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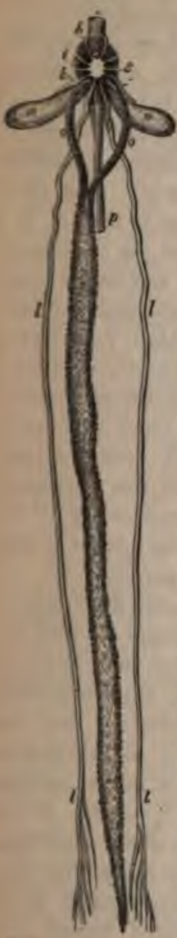
* [illegible]

† Ib. c.

45



Nervous System and female organs of generation.
Linguatula, magnified.

In the *Linguatula tænioides* (*fig.* 45.), a proportionally large ganglion (*g*) is situated immediately behind the mouth, and below the œsophagus, which is turned forward in the figure at *o*: small nerves (*h*, *i*, *k*) radiate from this centre to supply the muscular apparatus of the mouth and contiguous prehensile hooklets; and two large cords (*l*, *l*) pass backwards, and extend along the sides of the abdominal aspect of the body to near the posterior extremity, where they expand and are lost in the muscular tissue.† There is also a stomato-gastric system, represented by four small but distinct ganglions situated on the under part of the œsophagus, from which minute filaments extend along the alimentary canal.‡ I have already alluded to the evidences of the nervous system afforded by the ocelli in the young of some species of *Trematoda*, and in the full-grown *Polystoma* of the urinary bladder of the toad and frog. We have as yet no evidence that any species of *Cœlelmintha* possesses rudimental organs of vision at any stage of existence.

The digestive organs are very simple, and are subject to little variety in the Nematoid worms; an ample alimentary canal, suspended to the parietes of an abdominal cavity, extends in nearly a straight line from the mouth to the anus, which are at opposite extremities of the body.

In the *Filaria* the mouth is a simple circular pore, sometimes surrounded by a circle of radiated papillæ; a short and slender œsophagus suddenly dilates into the stomach, which is fusiform, and indicates the beginning of the intestine by its posterior contraction.

The mouth of the *Trichocephalus dispar* is small and orbicular; the œsophagus is narrow and short; the intestinal tube is narrow and sacculated where it occupies the filiform division of the body, dilated and simple in the thicker division of the body, at the posterior extremity of which it terminates in a contracted straight tube, which may be called the rectum: the anus is transverse and bilabiate.

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* This arrangement is denied by Siebold, who confirms only that above described in the *Strongylus*; and he does not hesitate to declare: — "Die Abbildung eines doppelten Nervenfaden, welcher sich nach Grant (Outlines of Comp. Anat., p. 186. fig. 82. A.), durch den Leib von Ascaris hinziehen soll, ist wol nur eine ideale Zeichnung." XXIV. p. 126.

† LXXXVII. p. 328. pl. 41. figs. 12, 13.

‡ XCII.

In the *Strongylus gigas* the mouth is surrounded by six papillæ. The œsophagus (*b, fig.* 44) is round, slightly bent, and suddenly dilates at the distance of about an inch from the mouth into the intestinal canal (*c*); there is no gastric portion marked off in this canal by an inferior constriction, but it is continued of uniform structure, slightly enlarging in diameter to the anus (*d*). The chief peculiarity of the intestine in this species is that it is a four-sided and not a cylindrical tube, and the mesenteric processes pass from the four longitudinal and nearly equidistant angles of the intestine to the abdominal parietes. These processes, when viewed by a high magnifying power, are partly composed of fibres, and partly of strings of clear globules, which appear like moniliform vessels turning around the fibres. The whole inner surface of the abdominal cavity is beset with soft, short, obtuse, pulpy processes, which probably imbibe the nutriment exuded from the intestine into the general cavity of the body and carry it to the four longitudinal vessels, which traverse at equal distances the muscular parietes.

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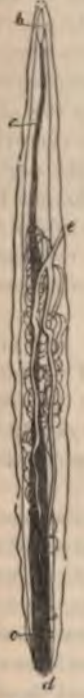

Ascaris lumbricoides. Half nat. size.

The analogous processes are more highly developed in the *Ascaris lumbricoides*, in which species I shall describe the digestive and nutritive apparatus more in detail. The mouth (*fig.* 46, *a*) is surrounded by three tubercles, of which one is superior, the others inferior; they are rounded externally, triangular within, and slightly granulated on the opposed surfaces, which form the boundaries of the oral aperture. The longitudinal muscles of the body are attached to these tubercles; the dorsal fasciculus converges to a point to be inserted into the superior one; the ventral fasciculus contracts, and then divides, to be inserted into the two which are situated below. By means of these attachments the longitudinal muscles serve to produce the divarication of the tubercles and the opening of the mouth: the tubercles are approximated by the action of a sphincter muscle.

The œsophagus (*fig.* 46, *b*) is muscular, and four or five lines in length, narrow, slightly dilated posteriorly, and attached to the muscular parietes by radiated filaments. Its cavity is occupied by three longitudinal ridges, which meet in the centre of the canal. It is separated by a well-marked constriction from the second part of the alimentary tube (*c*, *c*), which extends to the terminal outlet (*d*) without presenting any natural division into stomach and intestine. The lower third of the tube is the widest. Numerous long pyriform villi project from the mucous lining of the alimentary canal. Many minute filaments pass from the intestine to the soft obtuse papillæ which project from the walls of the abdomen into that cavity, and which are called "the nutritious appendages" by Cloquet.* The nutriment which these processes or appendages are presumed to imbibe, is collected, according to the same author, into two canals, situated each in a narrow tract of opaque substance, which extends along the sides of the body, and has sometimes been mistaken for a nerve, and which Vallisnieri believed to be a trachea. Morren has lately described and figured the nutritive appendages as hollow vesicles: he calls them "*Vésicules aériennes*," because, he says, "they evidently subserve respiration by furnishing air to the blood." Few physiologists are likely to acquiesce in this view, which makes the respiratory apparatus of an animal having no other atmosphere than the mephitic gases of the intestinal tube, the largest and most extensively developed organ in the whole body.

With reference to the organisation of the nematoid Entozoa, not parasites of the human subject, I shall limit my remarks to those structures which offer interesting approximations and analogies to the organisation of higher vermiform animals, and of the existence of which we must have remained ignorant if our attention had been wholly confined to the human Entozoa.

The entry to the mouth is beset by a circle of horny teeth in the *Strongylus armatus*, *Str. dentatus*, and *Str. tetracanthus*, for the movements of which special muscles are provided. In *Spiroptera strongylina* the whole inner surface of the elongated mouth is provided with a spirally disposed horny ridge. The horny apparatus by which the mouth in *Cucullanus* is opened and closed is very complex.† The pharynx is unusually long in some nematoids, e. g. the *Trichocephali*: and in *Trichosoma Falconum* it is divided into many successive segments: it has sometimes a horny scabrous lining.

I may next refer to a secreting apparatus, consisting of four slender blind tubes, each about two lines in length, which are placed at equal distances around the commencement of the alimentary canal in the *Gnathostoma spinigerum*, a small nematoid worm closely allied to *Strongylus*, which I discovered in the tunics of the stomach of a tiger.‡ The mouth of this Entozoon is a vertical fissure, bounded on each side by a jaw-like lip, the anterior margin of which is produced in the form of three straight horny points. The secerning tubes terminate at the mouth by their smaller extremities, and there pour out a semi-pellucid secretion. They are as simple as the so-called salivary cæca in the Holothuria; and their coexistence with a structure of the mouth, better adapted for trituration than any that seems hitherto to have been detected in the Entozoa, is conformable with the laws which regulate the coexistence of the salivary apparatus in higher animals. Cloquet supposes that the thickened glandular parietes of the œsophagus in the *Ascaris lumbricoides* may provide a secretion analogous to that of salivary organs. Diesing* has described four cæcal tubes analogous to those in *Gnathostoma* in species of his genus *Cheiracanthus*, in which he considers them, erroneously according to Siebold, to be analogous to the ambulacral vesicles in the Echinoderms. Mehlis† has also figured, in the *Strongylus hypostomus*, two white organs with blind extremities, which are extended into the abdominal cavity on each side the intestine, and which appeared to him to terminate in the animal's mouth. These glands Mehlis supposed to pour out an irritating liquor, which excited an increase of the secretion of the mucous membrane, to which the parasite was attached. Dr. Bagge‡, has more recently described a pair of blind secerning tubes in the *Strongylus auricularis* and in the *Ascaris acuminata*, which unite and terminate by a common transverse fissure on the exterior of the animal, at a short distance behind the mouth, and to which he assigns the same irritating office as that attributed by Mehlis to the glands in the *Strongylus hypostomus.*

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* LXXVIII.

† XXIV. p. 131.

‡ LXXXVIII.

The alimentary tube in a species of *Ascaris* infesting the stomach of the Dugong is complicated by a single elongated cæcum, arising at a distance of half an inch from the mouth, and continued upward, so that its blind extremity is close to the mouth. From the position where the secretion of this cæcum enters the alimentary canal, it may be regarded as a primitive rudiment of the liver.

The generative organs of the Cœlelmintha are more simple than in the androgynous Sterelmintha, or even than in the diœcious Echinorhynchi; yet they are adapted for the production of a surprising number of fertile ova. In the *Linguatula* the organs of both sexes, and especially of the female, are more complex than in the Nematoidea: I shall, however, briefly notice them before proceeding to demonstrate the parts of generation in the human cœlelminthic parasites.

The male *Linguatula*, as in other diœcious Entozoa, is much smaller than the female: the generative apparatus consists of two winding seminal tubes or testes, and a single vas deferens, which carries the semen from the testes by a very narrow tube, and afterwards grows wider. It communicates anteriorly with two capillary processes, or *penes*, which are connected together at their origin by a cordiform glandular body, representing a prostate or vesicula seminalis. The external orifices of the male apparatus, according to Miram, are two in number, and are situated on the dorsal aspect of the body just behind the head. Diesing, however, describes the male *Pentastoma* as having only a single penis, which protrudes just behind or below the oral aperture.

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* LXXXIX.

† XC. p. 81. taf. 2. fig. 6.

‡ LXXXV.

The female generative organs of the *Linguatula tænioides* present a structure in some respects analogous to that of the *Distoma perlatum*: the ovary (*fig.* 45. *n*) is a part distinct from the tubular oviduct, and is attached to the integument or parietes of the body, extending down the middle of the dorsal aspect. It consists of a thin stratum of minute granules, clustered in a ramified form to minute white tubes, which converge and ultimately unite to form two oviducts. These (*o*, *o*) proceed from the anterior extremity of the ovary, diverge, pass on each side of the alimentary canal, and unite beneath the origins of the nerves of the body, so as to surround the œsophagus and these nerves as in a loop. The single tube (*p*) formed by the union of the two oviducts above described, descends, winding round the alimentary canal in numerous coils, and terminates at the anal extremity of the body. But, besides receiving the ova from the two tubes, the single canal communicates at its commencement with two elongated pyriform sacs (*m*, *m*), which receive from the male, in coitu, the semen, and convey it into the oviduct, with the addition of a mucous secretion.

The male organs in the Nematoidea consist of a single and simple, slender, elongated tube (*fig.* 44, *e*, *e′*, *f*), or testis under its most elementary form of a sperm-duct, which is merely a contracted continuation of the tubular testis of a seminal reservoir, which is a wider part of the same tube, and of a single or double intromittent spiculum with its prepuce, or bursa.

The spiculum is simple in the genus *Filaria*. According to the observations of Dr. Leblond*, the male-duct in the *Filaria papillosa* terminates at the anterior extremity of the body, close to the mouth. From this aperture the slender duct, after a slight contortion, is continued straight down the body to a dilated elongated sac, which represents the testis. In the *Filaria attenuata* the blind end or beginning of the testis is bifurcate.

In the *Trichocephalus dispar* the testis, a single tortuous tubule, commences by a blind extremity near the rectum, passes forwards to a dilated seminal receptacle at the anterior part of the thick portion of the body, from which it bends backwards nearly the whole length of the thick part, constricted at irregular intervals, and terminating in a narrow straight canal, which is continued into the inverted pyramidal appendage, or bursa, attached to the hinder extremity of the body, from which the single spiculum projects.

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* LXXXII*. p. 20. pl. 3. f. 1.

In the *Strongylus gigas* the blind beginning of the testis is usually found in the anterior half of the body, as at *e* (*fig.* 44.), the tube descends into the posterior half, and is disposed in a number of long coils, reaching from near the head, *e′*, to the tail. One part of the canal is wider than the rest, and forms a kind of seminal reservoir. The terminal portion, *f*, is slender. The bursa or sheath of the penis forms the posterior extremity of the body, and is a cutaneous production of a round, expanded form, *d*, with the spiculum *e*, projecting from its centre. In other species of *Strongylus*, as e. g. *Strong. inflexus*, the bursa penis is bifid, and the intromittent organ is double: both divisions are of great length in the *Strongylus paradoxus*: in the *Strongylus armatus* the bursa is quadrifid. The *Spiropteræ* are distinguished by the aliform membranous caudal appendage in the male.

In the *Ascaris lumbricoides* the penis projects from the anterior part of the anus in the form of a slender, conical, slightly curved process, at the extremity of which a minute pore may be observed with the aid of the microscope. The base of the penis communicates with a seminal reservoir, and is attached to several muscular fibres, destined for its retraction and protrusion: the reservoir is about an inch in length, and gradually enlarges as it advances forwards: the testis, or seminal tube, extends to the anterior third of the body, forming numerous convolutions or loops about the intestine: its attenuated cæcal extremity adheres closely to the dorsal wall of the abdomen. The total length of the seminal tube is about three feet. In the *Ascaris mystax* the basal half of each long and slender penis is tuberculate for the attachment of its protractor and retractor muscles: the apical half, which alone is protruded, is a slender transversely striated horny spiculum. Accessory parts to aid mechanically in the coitus are added to some of these limbless vermiform parasites. In the *Ascaris mystax*, e. g., there is on either side of the concavity of the caudal end of the body a tubercular ridge supporting a membrane which is finely serrated, and gives a secure hold when the tail of the male is wound round that part of the female's body where the vulva is situated.

The first steps in the development of the spermatozoa of the Nematoidea have been well observed by Siebold * in the *Ascaris paucipara*, a species favourable for this kind of research, on account of the large size of the sperm-cells. The blind end of the tubular testis is occupied by cell-nuclei (zellenkerne) with their nucleoli (kernkörperchen). A little further on a quantity of very fine granular matter is added, and the cell-nuclei become severally enclosed (eingehüllt) by the fine granular matter, as by a yolk; around which envelope a cell-membrane is formed. This cell-wall gradually expands; its inner surface being lined by a layer of granules, whilst in the cavity of the cell the granules have liquified and disappeared. As these changes take place the cell-nucleus becomes developed into an elongate, sharply defined solid corpuscle, which is the spermatozoon.

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* XXIV. p. 153.

The observations recently communicated to the Royal Society by Dr. Nelson * on the development of the spermatozoa in the *Ascaris mystax*, correspond in the main with Siebold's description. Dr. N. finds the blind end of the testis composed of a thick membrane, which becomes resolved at its inner surface into very minute granules, which, when liberated, swell out into nucleated cells. A little further on these cells are obscured by an immense number of fine granules, which form envelopes for the cells. These cells, which are described to have a very transparent cell-wall and a nucleus attached to one side, answer to the "zellenkerne" of Siebold. According to Dr. Nelson no further development of the spermatozoon goes on in any part of the testis, but is reserved for the transmission of the semen into the uterine tube of the female. Here he describes the sperm-cells as being deprived of their granular envelope and becoming enlarged, forming transparent spheres, with a discoid nucleus which now contains a nucleolus. The granular substance of the nucleus increases and projects towards the centre of the cell, and its external layer is converted into a distinct tunic, where it is in contact with the cell-wall, which, as the nuclear matter increases, sometimes pushes out the cell-wall. This, however, does not form the tail-part of the spermatozoon in *Asc. mystax:* the change of the conical to the cylindrical form of the progressively elongating nuclear matter takes place within the sperm-cell, close to its wall. The nucleolus remains in the enlarged or clavate end of the bent cylinder, but the granules disappear, and the nucleus is transformed into a flask-shaped cæcal tubule, which is liberated, as the spermatozoon, by the liquefaction of the surrounding cell-wall. The nucleolus at the open clavate end of the spermatozoon afterwards disappears.

From the examples which have been adduced of different genera of the Nematoidea, we may perceive that although there are many varieties of structure in the copulative part of the male generative apparatus, the essential or secerning portion uniformly consists of a single tube. A like uniformity of structure does not obtain in the essential parts of the female organs: in a few instances the ovary is

* XCI.

single, corresponding to the testis in the male, but in the greater number of the nematoid worms it consists of two filamentary tubes.

The *Strongylus gigas* is an example of the more simple structure above alluded to.* The single ovary commences by an obtuse blind extremity close to the anal extremity of the body, and is firmly attached to the termination of the intestine; it passes first in a straight line towards the anterior extremity of the body, and, when arrived to within a short distance from the vulva, is again attached to the parietes of the body, and makes a sudden turn backwards; it then forms two long loops about the middle of the body, and returns again forwards, suddenly dilating into an uterus, which is three inches in length, and from the anterior extremity of which a slender cylindrical tube or vagina, about an inch in length, is continued, which, after forming a small convolution, terminates in the vulva, at the distance of two inches from the anterior extremity of the body.

In the *Trichocephalus dispar* the ovarium and uterus are continuations of one and the same single tube, which by its folds more or less conceals the intestines; the vulva is situated nearly at the junction of the filamentous with the thick part of the body. The female generative tube is, also, single in *Trichosoma*, in *Sphærularia*, in *Filaria rigida*, and in *Ascaris paucipara*.

The theory which had suggested itself to Rudolphi, of the correlation of a simple oviduct in the female with the spiculum simplex of the male, and of the double oviduct with a spiculum duplex, is disproved by the circumstance of the uteri and oviducts being double in the *Strongylus armatus* and in the *Ascaris lumbricoides*, in the males of which the penis is a single spiculum. In the *Strongylus inflexus*, which infests the bronchial tubes and pulmonary vessels of the porpoise, each of the two female tubular organs may be divided into ovary, oviduct, and uterus; the ovary is one inch in length, commences by a point opposite the middle of the body, and, after slightly enlarging, abruptly contracts into a capillary duct about two lines in length, which may be termed the oviduct or Fallopian tube, and this opens into a dilated moniliform uterus three inches in length. Both tubes are remarkably short, presenting none of the convolutions characteristic of the oviducts of *Ascaris* and *Filaria*, but extend in a straight line (with the axception of the short-twisted capillary communication between the ovaria and uteri) to the vulva, which forms a slight projection below the curved anal extremity of the body. The reason of this situation of the vulva seems to be the fixed condition of the head of this species of *Strongylus*. In both sexes, it is commonly imbedded so tightly in a condensed portion of the periphery of the lung, as to be with difficulty extracted; the anal extremity, on the contrary, hangs freely in the larger branches of the bronchi, where the coitus, in consequence of the above disposition of the female organs, may readily take place.

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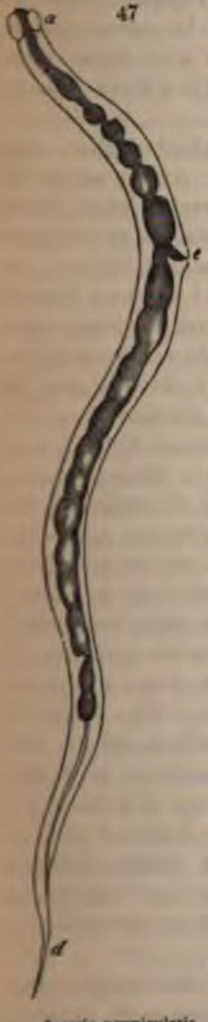
* LX. p. 141. fig. 95.

47



Ascaris vermicularis (magnified).

In the *Strongylus armatus*, the two oviducts terminate in a single dilated uterus, and the vulva is situated at the anterior extremity of the body, close to the mouth.

I find a similar situation of the vulva in a species of *Filaria*, about thirty inches in length, which infests the abdominal cavity of the *Rhea*, or American ostrich. The single portion of the genital tube continued from the vulva, is one inch and a quarter in length; it then divides, and the two oviducts, after forming several interlaced convolutions in the middle third of the body, separate; one extends to the anal, the other to the oral extremities of the body, where the capillary portions of the oviducts respectively commence.

In the *Ascaris vermicularis*, the vulva (*fig.* 47, *e*) is situated about one fourth of the length of the body from the head. One division or horn of the uterus, with its capillary ovarium, passes towards the forepart of the body; the other division towards the opposite end.

In the *Ascaris lumbricoides* the female organs (*fig.* 46.) consist of a vulva, a vagina, and a uterus, which divides into two long tortuous oviducts, gradually diminishing to capillary tubes, which form the ovaria. Both divisions extend backwards from the point of bifurcation. All these parts are remarkable in the recent animal for their extreme whiteness. The vulva is situated on the ventral surface of the body, at the junction of the anterior and middle thirds of the body, which is generally marked at that part by a slight constriction. The vagina is a slightly wavy canal five or six lines in length, which passes beneath the intestine, and dilates into the uterus. This manifests strong peristaltic motions in the living worm. The division of the uterus soon takes place, and the cornua extend with an irregularly wavy course to near the posterior extremity of the body, gradually diminishing in size; they are then reflect forwards, as the ovaria, and form numerous, and apparently inext cable coils about the two posterior thirds of the intestine. The vagin like the uterus, is lined by flat nucleated epithelial cells.

In *Cucullanus elegans* and *C. microcephalus* the uterus is bif but only one of the divisions is prolonged into the capillary ovarium the other horn terminates abruptly in a blind end. In *Ascaris micr cephala* Siebold found the uterus to divide into three horns, eac of which was produced into an ovarium: and in *Filaria labiat* Nathusius saw the uterus divided into five tubes.*

In the *Nematoidea* the male individual is always smaller, an sometimes disproportionately so, than the female. At the season o reproduction, the anal extremity of the male is usually bent roun the part of the body where opens the vulva of the female, to which i attaches itself by the intromission of the single or double spiculum, an by the adhesion of the surrounding tumid labia, or of accessory derma appendages. As the vulva of the female is generally situated at distance from either extremity of her body, the male so attached ha sometimes the appearance of a branch or young individual sent o by gemmation at an acute angle to the body of the female.

The evidence of the fertility of the compound cestoid Entozoa wa sufficiently marvellous. That which I have now to adduce, from calculation made by Dr. Eschricht in reference to the *Ascaris lum bricoides*, the commonest intestinal parasite of the human species, i scarcely less surprising. The ova are arranged in the ovarian tube like the flowers of the plantago, around a central stem or rachi There are fifty in each circle; that is to say, you might count fift ova in every transverse section of the tube. Now the thickness each ovum is 1·500 of a line, so that in the length of one line the are 500 wreaths of fifty eggs each, or 25,000 eggs! The length each ovarian tube is sixteen feet, or 2,304 lines, which, for the tw tubes, gives a length of 4,608 lines. The eggs, however, graduall increase in size so as to attain the thickness of $\frac{1}{60}$ of a line; w therefore have, at the lower end of the tube, sixty wreaths of ova, 3,000 ova in the extent of one line. The average number, throu the whole of the extraordinary extent of the tube, may be given 14,000 ova in each line, which gives *sixty-four millions* of ova in t mature female *Ascaris lumbricoides!*

The embryo is not developed within the body in this species: t ova may be discharged by millions; and most of them must, in lar cities, be carried into streams of water. An extremely small p portion is ever likely to be again introduced into the alimentary canal of that species of animal which can afford it an appropriate habitat. The remainder of the germs doubtless serve as food to numerous minute inhabitants of the water; and the prolific Entozoa may thus serve these little creatures in the same relation as the fruitful Cerealia in the vegetable kingdom stand to higher animals, ministering less to the perpetuation of their own species than to the sustenance of man.

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* XXIV. p. 151.

The nematoid Entozoa present, perhaps, the most favourable subjects for studying, with the requisite attention, the successive steps of impregnation, and of the processes by which the germinal vesicle and yolk become finally transmuted into the young and active worm.

I described and showed diagrams of some of these changes in the ova of the *Srongylus inflexus* in my lectures on Generation in 1840. The subject has been carefully prosecuted by Professors Siebold* and Kölliker†, from observations made upon the ova of the *Strongylus auricularis* and the *Ascaris acuminata*, both of them viviparous species of *Nematoidea*, and subsequently by Dr. Nelson with great care and ability, in the oviparous *Ascaris mystax.*‡

The blind end of the tubular ovarium detaches from its inner surface, and contains, minute round cells, which, as they proceed along the tube, enlarge, become nucleated, and surrounded by a finely-granular yolk matter, in which the cell floats as the 'germinal vesicle' with its nucleus. In the more advanced part of the ovarium, these ova are discoid, of an irregular form, and disposed either in simple rows, one behind another, or are grouped round a stem or rachis in the centre of the tube, according to the species. In the oviduct, the ova acquire a colourless chorion, the secretion of that tube. A short diverticulum proceeds from each pole of the egg in *Trichosoma* and *Trichocephalus.*

In the fundus, or beginning of the uterus, much seminal matter is accumulated in the impregnated females.§ Dr. Eschricht describes fifty ova as forming a single whorl or wreath in the *Ascaris lumbricoides*: but in the *Ascaris mystax* Dr. Nelson found but four flattened ova in the same plane, filling the transverse section of the ovarian tube. They assume, by mutual pressure, a triangular form with the rounded base next the walls of the tube. In the contracted part of the canal, answering to that which I have called "oviduct" in the *Strongylus inflexus* ‖, the ova in the *A. mystax* become separated, and pass in single file to the uterus, altering their form during the passage, in which they first meet the spermatozoa; but whether these be present in the oviduct or not, the following changes take place. The ovum becomes spheroidal and acquires a chorion; the vitelline granules become smaller; the germinal vesicle disappears; and a number of large, transparent, oil-like globules appear, probably the combined result of the condensation of the yolk granules and the diffused contents of the germinal vesicle. The oil-like globules approach the circumference of the ovum, and disappear; the condensed yolk-mass assumes a spherical form in the centre of the egg: and the membrana vitelli is now recognised surrounding it, divided by a clear fluid from the chorion. If impregnation have not previously taken place, the chorion is granulated, and such ova perish without undergoing further developmental change.*

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* LXXXV.

† LXVI.

‡ XCI.

§ XXIV. p. 151.

‖ LXXXIV. p. 74.

When impregnation has taken place, the narrow oviduct is filled by the flask-shaped spermatozoa, and the ovum, as it passes singly into it from the ovarium, becomes surrounded by them. They indent the previously well-defined surface of the tenacious granular yolk, bury themselves in it, and partially break it up in the process. Sometimes only one spermatozoon is thus seen embedded; but more commonly several spermatozoa penetrate the same ovum. The germinal vesicle can be faintly recognised in some of these so penetrated ova. As the ova proceed along the impregnated oviduct, the chorion begins to be formed, as in the unimpregnated one. It appears at first upon the smooth unperforated parts of the ovum, and afterwards covers the ruptures themselves, and incloses the spermatozoa with the yolk and its germinal vesicle. The inclosed spermatozoa now lose their characteristic form, and swell into irregular masses having a distinct outline, and, being highly refractive, give a mottled appearance to the contents of the egg. They are then gradually resolved into a transparent fluid, diffused, and effect changes, by partial solution, on the yolk granules themselves, these changes proceeding from the surface towards the centre. The germinal vesicle remains for a while in the centre of the ovum, more or less surrounded by the undissolved yolk granules, whilst the egg acquires one or two additional layers of the chorion secreted by the oviduct. The germinal vesicle then ruptures or disappears; but its nucleus, with a now visible nucleolus, remains. The rupture of the germinal vesicle is followed by a change in the character of the remaining yolk granules, which become larger, less opaque, and float more loosely in the fluid. The nucleus begins to swell out into a transparent cell—the "primary germ-cell"†—of which the former nucleolus is now the nucleus; and the surrounding granules are aggregated about it by the formation of a yolk membrane, which compresses them into a spherical mass, the clear fluid being, as it were, filtered through, as the membrane contracts, into the interspace between the germ-mass and the chorion. In this state the egg quits the parent in the *Asc. mystax.*

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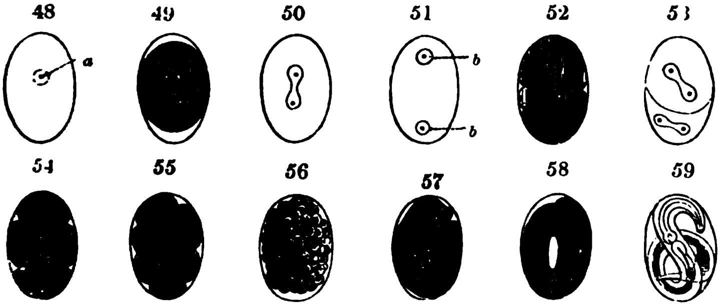
* XCI.

† First defined under that name, and so distinguished from its predecessor the "germinal vesicle," in XXX. pp. 4, 5.

The subsequent changes observed by Dr. Nelson in this species accord with those which have been described by Barry, in the mammiferous ovum [*], and by Siebold [†], Kölliker [‡], and other observers, in the impregnated ova of the Entozoa and other invertebrate animals. The nucleus of the primary germ-cell (*fig.* 48, *a*) first divides. Its division (*fig.* 49.) is followed by that of the germ-cell itself (*fig.* 50.); and the two "secondary germ-cells" (*fig.* 51, *b*, *b*) thus established, recede to opposite ends of the germ-yolk. Dr. Nelson has observed that these germ-cells revolve in circles, each appearing to mould its portion of the germ-yolk into a spherical form; and he considers the subsequent division of the germ-yolk to be a mechanical effect. [§] By its division, two germ-yolks, each with its nucleated germ-cell, result (*fig.* 52.). The division of the germ-cell takes from five to ten hours; the subsequent one, of the yolk, not more than half an hour, in the *Asc. mystax.* By the repetition of this process, as in *figs.* 53, 54, 55, the number of derivative germ-cells increases in the geometrical ratio of 4, 8, 16, 64, 128, 256, &c., until the whole egg appears to be filled by opaque spherical granules (*fig.* 56.), each, however, having its share of the original impregnated germ-cell. A membrane is then formed around the germ-mass.



Development of *Ascaris acuminata.* LXXXV.

In the ova of Nematoidea, many of which are viviparous, the embryo is developed by two different modifications of the diffusive process by multiplication of germ-cells from the primary central one:

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[*] XXVII. p. 307. [†] LXXXV. [‡] LXVI. [§] XCI.

in the one process the successive division of the germ-cells goes on without a corresponding cleavage of the yolk, but this is penetrated by the multiplying germ-cells, is absorbed, assimilated, and converted into the matter of such germ-cells: in the other process the attractive force of the germ-nuclei seems to be greater; the whole yolk is divided by the first bipartition of the original germ-cell, and is afterwards assembled around these divisions, as they successively arise, as in *figs.* 52—56. The subdivisions of the yolk decrease in size as they augment in number, and the vitelline matter is at length, by the reiterated processes of developement, liquefaction, and assimilation of nucleated cells, sufficiently subdivided and refined, and each subdivision or cell, by the concomitant partition of the clear spermatic nucleus or hyaline, has become adequately vitalised or fertilised, so as to be capable of its further metamorphosis into the appropriate tissues of the embryo worm.

So far the process is essentially the same with that in all other ova up to the mammal, and without doubt in man. The materials for the future being are accumulated in a duly subdivided state, like the bricks or hewn stones collected for the builder to operate on under the guidance of the architect. With regard to the rough material for formation of the *Ascaris*, a depression first appears on one side of the minutely subdivided germ-mass, which, as this deepens, assumes the form first of a cup, and then of a ring: the space so formed between the germ-mass and the chorion becomes filled by a clear fluid. The ring next presents a constriction at one point, which divides and transforms it into a cylinder with two equal obtuse ends in apposition (*fig.* 57.). By the lengthening and attenuation of the cylindrical mass, the ends overlap and the ring assumes the character of a coil (*fig.* 58.); and now something like an integument, containing a fine granular tissue, may be discerned. Further elongation and attenuation produce one or two spiral coils, and a greater clearness of the tissues of the embryo worm makes its character plainly manifest (*fig.* 59.). In the *Ascaris* at this period the characteristic three-lobed mouth may be discerned; and soon after the alimentary canal can be distinguished from the integument, both having been formed by the subdivision and metamorphosis of the primitive cells. The young animal, thus built up, now begins to move briskly within the egg-membrane, assimilates the remaining vitelline mass, and is soon strong enough to burst its prison, and commence its independent career of existence.

The Entozoa are hardly less remarkable for their tenacity of life and revival from a state of apparent death than the Infusoria, and the knowledge of this property is indispensable to a fair estimation of the chances of the re-introduction of the ova of Entozoa into the bodies of living animals. In no class of animals has the origin from equivocal generation been more strenuously contended for than in regard to the Entozoa. The great entozoologists Rudolphi and Bremser were advocates of this doctrine; and Bremser did not scruple to charge the Berlin Professor with a physiological heresy, when he ventured to account for the high organisation of certain Ligulæ infesting piscivorous birds, by the hypothesis that they had been developed from the lower grade which they previously exhibited in the cold-blooded fishes swallowed by the birds, through the stimulus of the heat and nutritious secretions of the more comfortable intestinal domicile into which they had thus been accidentally introduced.

The advocates for the equivocal generation of the Entozoa adduce the fact, that herbivorous mammals are not less subject to Entozoa than carnivorous ones; and how, they inquire, could the ova of Entozoa be preserved in the water that serves as the drink of such animals? Or how, having become dried in the air, could such ova afterwards resume the requisite vitality for embryonic development? We may admit that the ova of Entozoa could not, like the much more minute germs of Polygastria, remain suspended in the atmosphere, since they are specifically heavier than water; but, with respect to their powers of retaining dormant life, we have sufficient analogical evidence to reject the assumption that they soon fall into decomposition. Dr. Nelson * found that he could best observe the development of the ova of the *Ascaris mystax* by placing the females entire in spirit of turpentine for two or three weeks, at the end of which the ovaries were found distended with ova containing young worms, not only fully developed but alive, and endeavouring to rupture the chorion by tightening the coils of their spiral and suddenly reversing them.

Mr. Bauer has recorded many experiments on the *Vibrio tritici*, or parasite of wheat, a minute worm possessing the essential organisation of the Nematoidea, not less remarkable in their results than those of Spalanzani on the Rotifer; the Vibriones were dried, and when re-moistened, after the lapse of four to seven years, they resumed their living and active state. De Blainville states that the *Filaria papillosa* revives from a similar state of torpidity produced by desiccation.

It has been proved that the mature Entozoa will resist the effects of destructive agents, as extremes of heat and cold, to a degree beyond the known powers of endurance of the Rotifera, and which would be truly surprising were not the simplicity of the organisation of the

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* XCI.

Entozoa taken into account. A nematoid worm has been seen to exhibit strong contortions — evident vital motions — after having been subjected above an hour to the temperature of boiling water, with a codfish which it infested; and, on the other hand, Rudolphi relates that the Entozoa of the genus *Capsularia*, which infest the herrings that are annually sent to Berlin, hard frozen and packed in ice, do, when thawed, manifest unequivocal signs of restored vitality. If, then, the fully developed and mature Entozoa can resist such powerful extraneous causes of destruction, how much more must the ova possess the power of enduring such without losing their latent life!

Burdach, who has summed up the evidence at great length in favour of the equivocal generation of the Entozoa, adduces the example of the oviparous species as involving the limitation of the offspring to the lifetime of the individual which they themselves infest; but on this point Dr. Eschricht has well observed that the transmission of the living young of the *Strongylus inflexus* from one porpoise to another is readily explicable. This species of *Strongylus* lives in the bronchial tubes, with its head immersed in the substance of the lungs, and its tail extended into the larger branches of the trachea. The living young must naturally escape into the mouth, and, as porpoises are gregarious, the young worms would, by a short passage through the water, readily be introduced into the mouth of another porpoise, and so reach the trachea.

The young of most Entozoa are subject to metamorphoses. I have already alluded to those of the Cestoidea, in which the embryo assumes the form of an echinococcus, the head being provided with six hooks. So armed it is enabled to attach itself to the species of animal in which it becomes encysted and undergoes its next transformation: and such species, being the food of the higher organised animal in which the ultimate metamorphosis of the tænia takes place, the pupal tape-worm is in that way introduced into its final abode. So far as observations have yet gone, two different animals, having the mutual relation of prey and devourer, are subordinated, so to speak, to the well-being of each species of tape-worm. The metamorphoses of the Trematoda are still more astonishing, and the locomotive condition of the earlier phases of the *Distoma* evidently relate to the securing their entry into the animal's body, which they are destined either temporarily in a larval state, or permanently, to infest. Siebold has noticed the difference of form between the young of the Echinorhynchi and their viviparous parents; and this difference was so great in regard to the viviparous *Filaria medinensis*, that Dr. Jacobson was led to suppose its multitudinous progeny to be parasites of the parasite. Dr. Eschricht has observed, that the flesh of fishes in summer is often studded with small worms, which, in one instance, he ascertained to be *Echinorhynchi;* and he suggests whether it may not be the breeding-place of such species, and whether the *Trichina spiralis* may not belong to the same category. But how these embryos (if they be embryos) are diffused through the intermuscular cellular tissue, can only be known after long and laborious investigations; and nothing is more true than that a particular inquiry will be required for each particular species.

Summary of the Classes, Orders, and Families of the Entozoa of Rudolphi:—

Class STERELMINTHA.

The nutrient canals or cavities excavated in the parenchyme of the body.

Order TÆNIOIDEA.

The head provided with two, four, or six acetabula, and usually with spines, either sessile or placed on a proboscis, or on tentacula.

Family *CYSTICA.*

No organs of generation; body terminated by a bladder filled with fluid. (All are, probably, tænioid larvæ.)

Genera: *Echinococcus, Cœnurus, Cysticercus.*

Family *SCOLECIDÆ.*

Body short, or moderately long; sometimes partially vesiculated, usually encysted; no generative organs. (All are, probably, larvæ.)

Genera: *Anthocephalus, Dibothriorhynchus, Floriceps, Gymnorhynchus, Hepatoxylon, Rhynchobothrium, Scolex, Tentacularia, Tetrarhynchus* (many species).

Family *LIGULIDÆ.*

Acetabula and spines obsolete; body solid, depressed, long, with a longitudinal furrow, not jointed, but finely striated transversely.

Genus: *Ligula.* (Those of fishes are, probably, larvæ.)

Family *CESTOIDEA.*

Body long, depressed, jointed, with male and female organs combined in each of the mature segments.

Genera: *Tetrarhynchus* (certain species), *Bothriocephalus, Tænia, Caryophyllæus.*

Order TREMATODA.

Body generally depressed, not jointed, with one or more acetabula; mouth an unarmed pore, from which a bifurcate or branched alimentary canal is continued, rarely provided with a vent. Male and female organs in the same individual; impregnation by reciprocal coitus.

Sub-order PENDULARIA.

Integument not ciliated and no spontaneous fission in the mature worms.

Genera: *Monostoma, Amphistoma, Distoma, Diporpa* (in conjugation *Diplozoon*), *Gasterostoma, Holostoma, Tristoma, Polystoma.* (*Gyrodactylus, Axine, Octobothrium, Aspidocotylus, Aspidogaster*, are all, probably, larvæ.)

Sub-order TURBELLARIA.

Integument ciliated in the mature worms.

Family *RHABDOCŒLA*, with a simple cylindrical alimentary cavity.

Genera: *Vortex, Derostomum, Gyratrix, Strongylostomum, Mesostomum, Macrostomum, Microstomum.* (Some of these are, probably, larvæ.)

Family *DENDROCŒLA*, with a ramified alimentary cavity.

Genera: *Polycelis, Monocelis, Planaria, Leptoplana, Eurylepta, Planocera, Thysanozoon.*

Order ACANTHOCEPHALA.

Body saccular, cylindrical, or subdepressed; head provided with an uncinated proboscis. A ramified vascular nutritive system. Sexes distinct.

Genus: *Echinorhynchus.*

Class CŒLELMINTHA.

An alimentary canal suspended in an abdominal cavity. The sexes distinct.

Order GORDIACEA.

Body filamentary and cylindrical; alimentary canal without anus.

Genera: *Gordius, Mermis,* (*Trichina,* probably a larva).

Order NEMATOIDEA.

Body elongated, cylindrical. Alimentary canal with both mouth and vent.

Genera: *Filaria, Trichosoma, Trichocephalus, Spiroptera, Strongylus, Ascaris, Oxyurus, Cucullanus, Hedrurus, Ancyracanthus, Gnathostoma, Cheiracanthus, Lecanocephalus, Liorhynchus, Physaloptera, Sphærularia, Anguillula.*

Order ONCHOPHORA.

Body depressed, subarticulate. Mouth provided with hooks. Anus distinct.

Genus: *Linguatula.*

LECTURE VII.

POLYPI.

Hydrozoa and Anthozoa.

THE two great divisions of Cuvier's *Zoophytes*, viz. the *Infusoria* and *Entozoa*, which have hitherto engaged our attention, approximate to the vermiform type; and each ascends by rapid steps to the confines of the articulate province. The remaining classes of the *Zoophytes* are constructed on the radiated type; and some of them, as the *Bryozoa* and *Acalephæ*, conduct to the molluscous series.

To-day I have to request your attention to the history of a race of animals almost as widely diffused, almost as numerous, and some of them hardly less minute than the *Infusoria*, with which we commenced the survey of the vermiform zoophytes. Our present subjects form at least three classes of radiated zoophytes, which have been grouped together under the common name of *Polypi*, on account of their external resemblance to the many-armed cuttle-fishes, which were so denominated by the ancient Greek naturalists. But the knowledge of the organised beings now called *Polypi*, as members of the Animal Kingdom, is of comparatively recent introduction: it cannot be dated further back than the time of Imperato* and Peyssonel.† Amongst those naturalists who have subsequently contributed to improve and extend the history of the Polypes, our countryman Ellis ‡ will always take a high rank.

A polype generally presents a soft cylindrical oval or oblong body, with an aperture at one of its extremities, which is surrounded by a coronet of long tentacula. In most of the class, this aperture leads to a simple digestive cavity, consisting of a stomach without intestine. In the highest organised group, the digestive sac is prolonged into an intestinal canal, which is bent upon itself, and terminates by a distinct anus opening upon the external surface. The organisation of the polypes is in general simple; their faculties are limited; and the vital phenomena, save those of irritability and contractility, are inconspicuous. Nevertheless the influence of the combined powers of some of the species, in modifying the crust of the earth, is neither slight nor of limited extent.

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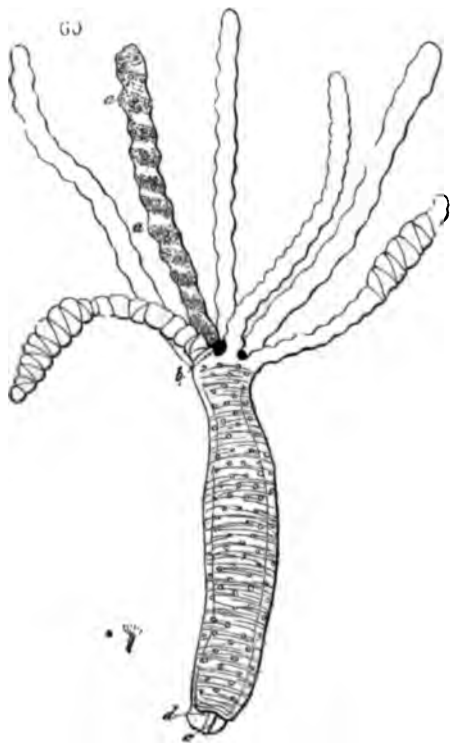
* XCV. (1599). † XCVI. (1723 and 1727). ‡ XCVII and XCVIII.

This great division of the radiated animals is divided into three groups or classes, according to the modifications of the alimentary canal. In the first and lowest organised class, which I have called *Hydrozoa**, digestion is performed by the secretion of a simple sac, excavated in the gelatinous and granular parenchyme of the body. In the second class, called *Anthozoa*, the digestive sac, which, like the first, throws out the rejectamenta by the same aperture as that which receives the nutriment, is suspended by a series of vertical folds of membrane, in a distinct abdominal cavity, to the outer parietes of the body. In the third and highest class, called *Bryozoa*, the alimentary canal, which is suspended loosely in an abdominal cavity, is provided, as has been already stated, with a distinct mouth and anus.



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Hydra fusca. * Nat. size.

It is remarkable that the most locomotive of the Polype tribe is at the same time the type of the lowest organised group. The *Hydra*†, or common fresh-water Polype (*fig.* 60.) consists, when magnified even with a moderately high power, apparently of a granular substance of a greenish or reddish hue, the granules or cells being loosely connected by a semi-fluid matter. The external cells are condensed, and elongated in the axis of the body, so as to form two tegumentary layers: the internal cells are elongated transversely to the axis of the body, and form a stratum of villi, projecting into the abdominal cavity: the thick intermediate mass of nucleated cells seems to fulfil the ordinary functions of muscular or contractile tissue.

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* LXXXIV. p. 82. *Dimorphæa* of Ehrenberg; *Sertulariens* of Milne Edwards; *Nudibrachiata* of Farre; *Hydroida* of Johnston; *Hydraidæ* and *Sertulariadæ* of E. Forbes.

† "In Africa et Arabia Hydras studiose frustra quæsivi," CXVII., p. 292.

The hydra commonly adheres by a small prehensile disc or rudimentary foot (*fig.* 60, *d*), situated at the extremity of the stem or body opposite to the mouth. When the little animal would change its position it slowly bends its body, and, fixing one or more of its tentacula to the supporting surface, detaches the foot, approximates it to the head, and advances by a succession of these leech-like motions. The hydra can make progress in water, as well as on a solid plane; when it would swim it suspends itself to the surface of the water by its terminal foot, which it expands, and exposes to the air: the disc soon dies, and in this state, repelling the surrounding water, it serves as a float, from which the hydra hangs with its mouth downwards, and can row itself along by means of its tentacula. Its ordinary position is one of rest, adhering to an aquatic plant by its foot, with the dependent oral tentacula spread abroad in quest of prey: these are of great length and tenuity in the *Hydra fusca.*

Should a small näis or entromostracan, or any of the larger infusories, come within the reach of the little carnivorous polype, they are immediately seized, pulled towards the mouth (*fig.* 60, *b*), and swallowed. The rapidity of the digestive process is manifested by the diffusion of any characteristic colour of the animalcules swallowed through the gelatinous parenchyme of the devourer; and when this process is completed, the indigestible *débris* of the prey are rejected by the same aperture which had just gorged it. The inner surface of the digestive bag is lined by a ciliated epithelium, and has many peculiar cells containing a clear fluid with brown pigment granules: these are very conspicuous in the *Hydra viridis;* the contents are probably discharged into the stomach by the bursting of the cells, which have been conjectured to perform a function akin to that of a liver. A careful investigator, Corda*, affirms the existence of an anal outlet (*fig.* 60, *c*), and figures it of small size, close to the hind sucker or foot; and Baker† several times saw "the dung of the polype in little round pellets discharged at this outlet or anus." Mr. Hancock‡, also, observing a *Hydra viridis* in a highly contracted state and about to discharge an egg, saw a narrow channel passing from the digestive cavity through the substance of the foot, apparently about its centre. From this channel issued a long, linear mass of excrementitious matter composed of a tenacious mucus imbedding a granular substance resembling both in colour and texture that which lined the digestive cavity. Such pore may give passage to certain excretions of the lining membrane of the cavity, but the coarser indigestible parts of the prey are habitually regurgitated by the mouth.

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* XCIX.

† C. p. 27.

‡ CIV. p. 288.

Each tentaculum in the *Hydra grisea*, according to Trembley, is a tube, which communicates with the common digestive cavity. The food which is rotated in that cavity is driven up some way into the tentacles, and sent back again.* Corda† found the walls of the tentacular cavities to contain a fluid albuminous substance mixed with oil-like particles. This substance swells out at certain definite places into denser nodules, which are arranged in a spiral line (*fig.* 60, *a*, *a*). Each nodule is furnished with tactile filaments, and a singularly constructed organ for catching and wounding the prey. The parts regarded by Corda as organs of touch consist of a fine sac, inclosing another with thicker parietes, and within this there is a small cavity: from the point where the two sacs coalesce above, there projects a long and very slender filament, which is non-retractile. The wounding or seizing organ consists of an obovate transparent sac, immersed in the nodule with a small aperture. At the bottom of the sac, and within it, there is a solid corpuscle, which gives origin to a clear calcareous sharp dart or spine, that can be pushed out at pleasure, or withdrawn until its point is brought within the sac. When the hydra wishes to seize an animal, the darts are protruded, by which means the surface of the tentacula is roughened, and the prey more easily retained: Corda believes that a poison is at the same time ejected. The nodules of the tentacula are connected together by means of four muscular bands, which run up, forming lozenge-shaped spaces by their intersections: these are joined together by transverse bands.‡ The lip of the mouth is armed with darts similar to those of the tentacula; and they have been found in the skin of the body and of the foot.

That the tentacula have the power of communicating some benumbing or noxious influence to the living animals which constitute the food of the Hydra, is evident from the effect produced, for example, upon an entomostracan, which may have been touched, but not seized, by one of these organs. The little active crustacean is arrested in the midst of its rapid, darting motion, and sinks, apparently lifeless, for some distance; then slowly recovers itself, and

* CI. tom. i. p. 260., tom ii. p. 228.

† XCIX.

‡ CIV. p. 85.

resumes its ordinary movements. Siebold states that when a naïs, a daphnia, or the larva of a Cheironomus have been wounded by the darts, but not seized, they do not recover, but die.* These and other active inhabitants of fresh waters, whose powers should be equivalent to rend asunder the delicate gelatinous arms of their low-organised captor, seem paralysed almost immediately after they have been seized, and so countenance the opinion of Corda that the secretion of a poison enters the wounds.

The most extraordinary properties of the Hydra are, however, those which best accord, and might be expected to be associated, with its low and simple grade of organisation; although they excited the greatest astonishment in the physiological world when first announced by their discoverer, Trembley†, and are often still called wonderful.

If a polype be partially bisected, each portion forms a perfect polype: Roesel‡ devotes three plates to figures of monstrous Hydræ, the results of such incisions. If a Hydra be transversely bisected, both halves survive; the cephalic one developing a terminal sucker, the caudal one shooting forth a crown of tentacula; each moiety thus acquiring the characters of the perfect individual. But in a healthy and well-fed Hydra, the same phenomena will take place if it be divided into ten pieces. The Hydra, notwithstanding the want of a nervous centre thus indicated, and the absence of any hitherto recognised nervous filaments, manifests an obvious predilection for light, and, when confined to a glass, always moves itself to the brightest side. Trembley succeeded in inverting these delicate animalcules, and retaining them inverted until they accommodated themselves to this singular change in their condition. The pigment or hepatic cells of the gastric membrane, now external, are cast off: the orifices, by which the cavities of the tentacula communicate with the stomach, are exposed a little below the rim of the mouth; these orifices are soon obliterated, and new ones are formed in communication with the new digestive sac. The ciliated epithelium and hepatic-cells must be developed on what was the outer surface: and the dart-cells in what before was the gastric surface. At least Trembley assures us, and gives corroborative evidence, that digestion was effected as actively by the surface which before was external, as by that which had been the digestive surface; whilst this as readily assumed the ordinary gemmiparous function of the skin.§

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* XXIV. p. 30. † CI. ‡ CV. (Tab. lxxx., lxxxi., and lxxxii.)

§ J'ai retourné un nombre considérable de Polypes de la seconde espèce

The Hydræ are not less remarkable for their power of generation than for that of regenerating mutilated parts. They have been observed to multiply by spontaneous fission, dividing themselves transversely. Roesel* figures a specimen in the act of transverse fission; but there may have been some previous injury at the part. The most ordinary process of generation is by the development of young polypi, like buds, from the external surface of the old one. This property depends on the small amount of change which the germ-mass has undergone in the development of the body.

In the freshwater polype, the progeny of the primary impregnated germ-cell retained unaltered in that body, may set up, under favourable stimuli of light, heat, and nutriment, the same actions as those to which they owed their own origin; certain of the nucleated cells do set up such actions, those, *e. g.* in the *Hydra fusca*, which are aggregated near the adhering pedicle or foot; and the result of their increase by assimilation and multiplication is, to push out the contiguous integument in the form of a bud, which becomes the seat of the subsequent processes of growth and development; a clear cavity or centre of assimilation is first formed, which soon opens into the stomach of the parent; but the communication is afterwards closed, and the young hydra is ultimately cast off from the surface of the parent. This mode of propagation is termed "gemmation." It differs from the development of the hydra *ab ovo*, inasmuch as the impregnated germ-cell, which set on foot the process, is derivative and included in the body of the adult, instead of being primary and included in a free ovum. But the germ-cell is the essential part of the ovum, and the chorion an accessory and non-essential part.†

According to my observations, buds are not developed indifferently from any part of the polype. I have never seen one growing from a tentacle, nor does a wound of this part lead to the development of a young hydra, like a wound of the base of the body. I conceive that the greater amount of metamorphosis which the germ-cells and nuclei have undergone in the formation of the complex organs of the tentacula is the condition of this inferior power of generation and regeneration.

The very small size in relation to the entire body, and the superficial position of the secondary germ-cell which takes on the pro-

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(*Hydra grisea*), "qui sont restés retournés et qui ont longtemps vécu. Ils ont mangé, cru et multiplié." CI. t. ii. p. 224.

* CV. tab. lxxxiii. fig. 3.

† Mr. Goodsir gives the name of ovule to the germ-cell which sets on foot the analogous process of bud-formation in the Cœnurus (LIII. p. 570).

cesses of development in the Hydra, appear to be the chief conditions influencing that modification of the generative process by which a small portion only of the Hydra is taken into the system of the new individual, instead of one-half of the body, as in the case of the Monad. So insignificant is the distinction between gemmation and spontaneous fission; the essential condition of both being, as in the development of the ova, the presence of the pellucid nucleus of a secondary impregnated germ-cell, as the centre from which all the processes in the formation of the new individual radiate.

The Hydra propagates by ova as well as by buds. It even presents a periodical development of sexual organs of two kinds: one, at the anterior or oral extremity of the body, consists of small nodules or sacs, which Ehrenberg discovered to contain moving filaments, or seminal animalcules; another series of cells, developed in the posterior part of the stem, contain ova. Sometimes one individual Hydra developes only the male cysts, or sperm-vesicles; sometimes only the female ones, or ovisacs; but the rule is generally to have both kinds.

The ova are spherical, with a bristled chorion, which is of a deep brown colour in the *Hydra fusca*. In the formation of the ova, certain of the retained germ-cells multiply themselves, and coalesce to form a larger central cell, surrounded by others of smaller size, with nuclei, the exterior of which cells are metamorphosed into a chorion. Certain other germ-cells are converted into sperm-cells, and develope spermatozoa. The ova are extruded and fertilized by these, and they develope a hydra, retaining, however, a large proportion of unchanged cells in its composition. Accordingly, this hydra may propagate by buds, and the hydra so developed may propagate again by ova, and these two kinds of generation may alternate indefinitely: but it usually happens that the same Hydra, after having exhausted its power of forming buds, then developes the eggs.

The seas which wash our own shores are tenanted by numerous forms of minute Polypi, having essentially the same simple organisation as the Hydra; but which are protected from the dense briny element by an external horny integument. Now these likewise develope new polypes by gemmation; but, as the external crust grows with the growth of the soft digestive sac, the young polype adheres to the body of the parent, and, by successive gemmations, a compound animal is produced. Yet the pattern according to which the new polypes and branches of polypes are developed is fixed and determinate in each species; and there consequently results a particular form of the whole compound animal or individual by which the species can be readily recognised (*fig.* 61.). This compound

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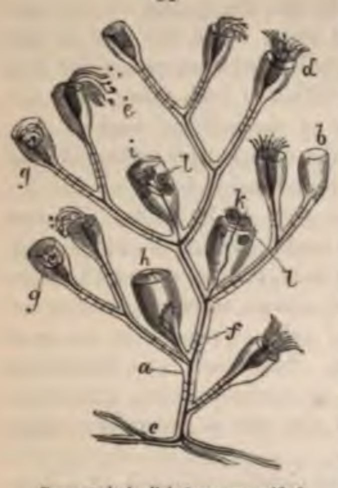

Campanularia dichotoma, magnified.

hydriform polype-animal, or association of polypes, resembles a miniature tree; but consists essentially of a ramified tube of irritable animal matter, *f*, defended by an external, flexible, and frequently jointed, horny skeleton, *a*; and is fed by the activity of the tentacula, *d*, and by the digestive powers of the alimentary sacs, *g*, of a hundred polypi, the common produce of which circulates through the tubular cavities for the benefit of the whole community. These currents of the nutrient fluid have been observed and described by Cavolini*, and more recently by Mr. Lister.† The genera *Sertularia*, *Campanularia*, *Tubularia*, &c., which form the principal subjects of Ellis's beautiful and classical work on Corallines, compose the present division of the compound *Hydrozoa*, or hydriform polypes. The soft integument of the nutrient polypes (*fig.* 61, *d*, *e*, *g*) is characterised by peculiar cells, like the "dart-cells" of the Hydræ, which have a transparent firm cell-wall, containing a clear fluid, and extremely delicate, sometimes spirally disposed, filaments. These are protruded when the skin is irritated, and give the tentacles the appearance of being beset by bristled prominences. The digestive sac of each polype is lined by a ciliated epithelium, and by hepatic cells, as in the Hydra: but its base is perforated by the hole which communicates with the tube, *f*, passing along the branch supporting the polype, to the general cavity of the stem. But this outlet allows only the fluid contents of the stomach to pass: the coarser rejectamenta are cast out by the mouth.

It appears that sea-water may have entry to these canals and circulate with the chyle, and so contribute some share to the respiratory process of the corallines. It is certain that sea-water is admitted to the corresponding cavities in the Anthozoa. Both Lister and Lowèn have observed an alternate imbibition and expulsion of water in the polypes of *Sertulariæ* and *Tubulariæ*. The chylaqueous fluid, as it may be termed, which circulates in the general ramified cavity of the coralline is colourless, and contains only some minute round corpuscles. This fluid is sent into the cavities of the prehensile arms, and returns back into the digestive cavity. The movements of the fluid appear to depend on a delicate ciliated epithelium which lines the cavities of the tentacles, as well as the tubular cavities of the stem and branches of the compound polypes.*

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* CVI.

† CVII. p. 299.

The peculiar external horny defence prevents, as I have just observed, the exercise of the gemmiparous faculty from effecting any other change than that of adding to the general size, and to the number of prehensile mouths and digestive sacs, of the compound coralline. It is equally a bar to propagation by spontaneous fission; so that the ordinary phenomena of generation by ova or germ-masses are more conspicuous in the composite than in the simple *Hydrozoa.* At certain points of these ramified polypes, which points are constant in, and characteristic of, each species, there are developed little elegant vase-shaped or pod-shaped sacs, which are called the ovigerous vesicles or "ovicapsules." These are sometimes appended to the branches, sometimes to the axillæ, as at *h*, *i*, *k*, *fig.* 61, of the ramified coralline: they are at first soft, and have a still softer lining membrane, which is thicker and more condensed at the bottom of the vesicle: it is at this part that the ova or germs are developed, *h*, and for some time these are maintained in connection with the vital tissue of the polype by a kind of umbilical cord, *k*, *l*. In all the compound *Hydrozoa*, the ovicapsules are deciduous, and having performed their functions in relation to the development of the new progeny, drop off like the seed-capsules of plants. This phenomenon afforded to the early botanists an additional argument in favour of the relation of these ramified and rooted animals to the Vegetable Kingdom.

The species of the marine Hydrozoa which is most nearly akin to the fresh-water Hydra, is the *Tubularia indivisa*, beautifully figured in his fine work on the "Remarkable Animals of Scotland," by Sir John G. Dalyell†, who devoted thirty years to the careful examination of the animals of the Frith of Forth. In this species each individual is distinct, like the Hydra; it propagates its kind by gemmation, and has, also, great powers of reparation, reproducing its polype head and double crown of tentacles many times in succession. It also propagates by ova. These are formed in ovicapsules, aggregated in groups which proceed from the space between the long and the short tentacula; and, in proportion as the ovicapsules are developed, the tentacula begin to decay, and the whole flower-like head falls. When cast off, the head does not lose its vitality, but moves, for a few days, perhaps, and crawls off with the ovicapsules to some distance from the parent. A locomotive polype, which is called by Sir J. G. Dalyell a "hydra," escapes from each ovicapsule, crawls off, becomes attached, and developes the elongated stem and other characters of the *Tubulariæ*. The process of development has been well observed by M. Van Beneden* in another species of *Tubularia* (*T. coronata* Abildg.). There are numerous clusters of ovicapsules in the same position as in the *T. indivisa*. The capsules in each cluster are developed from the sides of a short stem, and become more pedunculate as they are situated nearer its extremity. The common nutrient cavity is continued into the stem, and sends off branches to enter the bases or pedicles of the capsules. The germ-cell makes its appearance between the end of this canal and the summit of the capsule, as shown in 1, *fig.* 62, which represents a young sessile ovicapsule detached from the ovarian stem, showing the portion of the nutrient canal continued into it and the germ-cell below. The nutrient and respiratory currents are continued from the general cavity of the body through the ovarian canal and its diverticula which enter the ovicapsules. The germ-cell is thus supplied with matter for its growth, which proceeds rapidly by the ordinary mode of multiplication of secondary germ-cells by spontaneous fission. As growth proceeds the ovicapsule expands, and the end of the nutrient diverticulum becomes surrounded by the germ-mass, into the middle of which the diverticulum seems now to dip, as shown in 2, *fig.* 62. The next change is the development of a series of lobes which push aside the diverticulum, as in 3: the lobes elongate into rudimentary tentacles, and the base of the inner series of tentacles begins to appear, as at *b*, 4: this stage is better seen when the ovisac is viewed under pressure as at 5. Where development has advanced thus far, the parietes of the ovicapsule rupture and the embryo escapes, as a young polype, with one series of tentacles, 6. It then becomes fixed, and begins to develope its tubular body and its inner series of tentacles as in 7, *fig.* 62.

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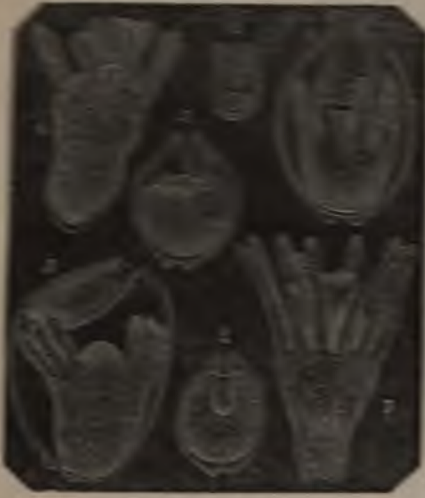
* CVIII. p. 107.

† CIX. pls. 1, 2, and 3.

62.



Development of Tubularia coronata.

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* CXI. p. 37. pl. i.

In a third species of *Tubularia* (*T. Dumortieri*) the embryo assumes the form of a transparent, gelatinous, longitudinally ribbed Beroë, before it escapes: and afterwards moves like a Medusa by alternate contraction and expansion of the body. The change of this medusoid larva into the *Tubularia* was not seen.

In the *Hydractinia rosea* V. Beneden found several ova, with the germinal vesicle and nucleus, developed in each ovicapsule.

The modification in the growth of the coralline to form the ovicapsule, has been compared by Professor E. Forbes* with that "metamorphosis in flowering plants in which the floral bud is constituted through the contraction of the axis and the whorling of the individuals borne on that axis, and by their transformation into the several parts of the flower." Many elegant varieties are observable in the form of the ovicapsules. Sometimes they are crossed by transverse bars; sometimes shaped like a vase, and provided with a little lid or cover; usually traversed along the middle by a continuation of the soft tissue of the polype, from which the ova or germs proceed, and which may be compared to an umbilical cord, and is termed the "placentarium." According to the botanical analogy, they may be either essentially "single individuals, ideally metamorphosed into reproductive organs comparable to the monocarpous germens of plants," or a "series of individuals joined together and merged into each other so as to present the appearance of an organic body in which the ova are reproduced comparable to the syncarpous germens" of plants; the pod-like ovicapsule of most *Plumulariæ* well illustrates the latter view.†

Ehrenberg ‡ regarded the ovicapsule as a modified individual, viz., a female generative polype, differing from the nutrient and sexless polype, in having the tentacula rudimentary or abortive. The contractile power of the ovicapsules in *Pennaria* and in *Syncoryne ramosa*, together with Lovén's description of the deciduous nursing-polypes developed from the ovicapsule in the *Campanularia geniculata*, gave apparent support to this view, which, however, later facts as to the nature of the progeny developed in the ovicapsule have induced most zoophytologists to abandon.

Sperm-capsules, similar in situation and form to the ovicapsules, are developed in certain individuals of the marine Hydrozoa. In *Pennaria Cavolini* the spermatozoa are developed in the interspace between the inner wall of the sperm-capsule and an axial cord of the soft tissue answering to the placentarium of the ovicapsule.§ In the *Tubularia*

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* CX.

† XCVII. pl. 11. B. (*Plumularia falcata.*)

‡ CXVII.

§ CXVI. p. 197.

indivisa, also, the sperm-capsules repeat the grape-like arrangement and situation of the ovicapsules. In *Eudendrium racemosum* the sperm-capsules are moniliform, and are supported on particular stems; the outermost capsules, which first appear, contain the best developed spermatozoa. These sperm-capsules were distinguished by Cavolini, as "uova a corimbo,"* from the ovicapsules, which he called "uova a racemo."† The distinguished Neapolitan zoophytologist also remarks that each kind of capsules occur in different individuals; and Krohn, to whom science is indebted for a determination of the true nature of the "uova a corimbo," found as a general rule that the sperm-capsules were developed in the *Eudendrium racemosum*, the *Plumularia cristata*, and *Sertularia misenensis*, on particular individuals or compound groups of individuals, the ovicapsules being developed on other such individuals.

The true ovum of the Hydrozoa has its germinal vesicle and spot, and after impregnation the germ-mass is formed by spontaneous fission of the germ-cells and cleavage of the granular yolk, as in the ova of the Ascaris (p. 113.).

In the Hydra this process goes on before the ovum quits the parent, and before it has acquired its bristled chorion. In the marine species the young may escape from the ovicapsule in the condition of ciliated locomotive bodies, called "planulæ" by Dalyell‡; or the planulæ may be hatched in the interior of a polype-individual developed from the summit of the ovicapsule, and which, after liberating them, may wither and fall like the flower of a plant§; or a generated individual of a particular form, such as e. g., the *Medusa octocilia* and *M. duodecilia* of Dalyell‖, developed from *Eudendrium ramosum*, and the *Tintinnabulum* or Bell-medusa observed by the same author as the progeny of the *Campanularia dichotoma*, may be developed in and escape from the ovicapsule, and, by its own power of locomotion, carry the contained ova to a distance from the composite and fixed group of nutritive individuals. The ova may be developed within the bell-shaped Acalephoid prior to its detachment, as in the *Coryne vulgaris*, observed by Wagner, or not until it has become detached and acquired the full characters of a bare-eyed Medusa.

The phenomenon of the development of a polype-like larva in the vesicles did not escape the keen eye of Ellis. He says, "I first perceived the polypes alive in the vesicles of the denticulated class of corallines, and particularly in this" —now the *Sertularia pumila:* —"these animals are of a much larger size in the vesicles than those in the denticles."* In another species (*Campanularia dichotoma*) he figures "the young polypes coming out of the vesicles, but still adhering to the umbilical chord." Dr. A. Farre has seen the development of the germ-masses, which are included in a delicate membrane and extend along the axis of the germ-vesicle, in the same *Campanularia:* the germs are covered by a ciliated epithelium; they then become bell-shaped medusæ, with marginal tentacles, and escape swimming freely. Mr. Lister's figures *b* 5 and *b* 6† show the little medusoids escaping from the germ-vesicles of the *Campanularia dichotoma;* but they are represented, as Ellis described them, as polypes. Abundant evidence has been afforded, especially by Dalyell, that Ellis did not, as Dr. Grant has stated‡, commit the error of mistaking mere ciliated locomotive gemmules or ova for young polypes. In many *Sertulariæ,* as Dalyell has shown, the young quit the germ-vesicles as locomotive ciliated animalcules, like Planariæ, which move not only by the cilia, but by a general contraction of the tissue. This kind of larva, which he calls "planula," crawls rather than swims, and in twenty-four hours presents the appearance of a disc with a series of peripheral rays; it then settles, expands, and a stem shoots up, developes a polype, and thus a new hydrozoal individual is generated. This metamorphosis, first observed and described by Cavolini § in the *Sertularia racemosa,* has been illustrated with accurate and minute details by Lovén.||

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* CVI. tab. vi. fig. 14. † CVI. tab. vi. fig. 6.

‡ CIX. p. 150. pl. xxiv. (*Sertularia abietina*), p. 162. pl. xxix. (*Sertularia halecina*).

§ CXII. p. 259. tab. vi. fig. 13. (*Campanularia geniculata*).

‖ CIX. pl. xi. figs. 9 and 11.

The more remarkable phenomenon of the medusoid form of larva is best shown in the claviform Corallines, and has been especially described by Lovén¶, in an excellent Memoir on the *Syncoryne ramosa* of Sars, and by Steenstrup in the *Coryne Fritillaria.*** This species originally developes a many-armed nutritive polype, or individual; but retaining many unchanged germ-cells, these, by the stimulus of the excess of nutriment, begin to repeat the process, and push out buds in an analogous position to that in the *Hydra fusca,* viz., around the base of the stomach of the first, or parent animal; but the buds, instead of repeating the form and condition of that animal, take on a higher form, resembling that of a bell-shaped Medusa; they become detached and swim off to a distance, forming

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* XCVII. p. 10. pl. v. A. also p. 21. and 23. pl. xxxviii. fig. 3. B.

† CVII. pl. x.

‡ CXIX. p. 54.

§ CVI. p. 261. tab. vi.

|| CXII. tab. vi. figs. 14—17.

¶ CXII.

** XCIII.

and discharging the ova, which, as Steenstrup conjectures, in their turn develope the fixed polype-shaped *Coryne*. This stage of the cycle has not yet been the subject of observation; but, by the analogy of the larger Medusæ, is the more probable process than that direct metamorphosis of the medusiform individual into the pedunculate polypoid individual, which V. Beneden has described by the aid of a conjectural figure in the *Tubularia*.*

In the *Eudendrium racemosum* Sir J. G. Dalyell observed the germ-vesicles containing the young medusoid animal to be developed from many parts of the parent stem. A very active movement of the inclosed animal may be seen near the mouth of the ovicapsule. It then opens; a small white bud protrudes, then some tentacula, in active struggling motion; and at last a little free-swimming medusoid animal appears, in the shape of a small bell. It courts the light, and manifests all the characteristics of the Acalephæ.

The medusiform ovigerous locomotive or distributive individual of the *Coryne Fritillaria*, and *Campanularia dichotoma* is obviously homologous with the polype-shaped ovigerous individual which seems to nurse, as it were, the ova into planulæ in the *Campanularia geniculata;* and the nutritive gemmiparous individuals in all the compound Hydrozoa would seem rather to manifest the typical form of the species, as the leaf is a more typical form of the plant than the parts of the flower. Superadd, however, distinct nutritive and circulating organs to the free-moving ovigerous individual, and prolong its existence, and it would then cease to have the subordinate character of a nurse to the ova of the fixed individuals, and would assume that of the perfected form of the species; and such, in fact, is the case with the larger gelatinous Radiaries called 'Medusæ.'

When the ovicapsule is the seat of development of a medusoid oviparous individual, as observed by Dalyell, the phenomena attending the escape of these are remarkable. Great exertions are made to force the orifice, until the animal finds its way out. The vessel of sea water in which specimens of *Eudendrium ramosum* have been kept is sometimes found crowded with the medusoid animalcules: this phenomenon much surprised the venerable Scottish Naturalist until he became aware of the origin of the little larvæ. His observations have been confirmed by Sars and others on the *Podocoryne* [illegible] and the *Coryne nutans*. In the same month in which Sars [illegible] the development of Medusoid animalcules from the *Podo-*[illegible], he found other specimens of *Podocoryne* developing [illegible] capsules containing ova. Steenstrup, who was more successful than Sars in preserving the life of the medusoid individuals, appears to have traced the phenomena of the development of the ova in them, and arrived at the conclusion that they are not directly transformed into the polype as Van Beneden believed to occur in the *Tubularia Dumortieri.* The ova so developed would give origin to "planulæ," and these, by the metamorphosis so well described by Dalyell, would produce the rooted zoophyte, from which a compound ramified group might result by successive incomplete gemmations. So that with regard to the generation of the marine Hydrozoa, we find these modifications: — either the ovicapsules are developed as buds on the nutrient polype which is cast off, and the young polype is afterwards developed in and escapes from the ovicapsule (*Tubularia indivisa*); or the ovicapsules are transformed polypes or pinnæ on different and determinate parts of the compound Hydrozoon, give issue to ciliated planulæ, and are cast off (most *Sertularia*); or bell-shaped Medusæ are developed in similarly formed ovicapsules, and escape (*Eudendrium ramosum*); or a small nursing polype is developed from the summit of the ovicapsule which incubates the ova, and falls like a flower (*Campanularia geniculata*); or Medusoids may be directly produced by gemmation, as in *Syncoryne,* and these, becoming detached, continue to move for some time (fifteen or eighteen days) before they fully develope the ova, which produce the planulæ, which are metamorphosed into the compound zoophyte.

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* CXI. pl. 2. fig. 5.

The medusoid brood, which V. Beneden saw to be the produce of the fixed and composite *Campanularia gelatinosa,* closely resemble those minute acalephæ which Sars* has described as the *Cytaeis octopunctata,* and Will† as *Cytaeis polystala.* With regard to the special capsule in which certain Hydrozoa produce locomotive larvæ of the acalephoid character, although it is called "ovicapsule," from its analogy to those that give issue to planulæ, it does not contain a proper "ovum" with its germinal vesicle, vitellus, and chorion, requiring the distinct act of impregnation before development of the medusoid embryo can begin. The development of such forms of embryo in the ovicapsules of the *Eudendrium ramosum* and *Campanularia dichotoma* seems to be the result rather of the last remnant of the old spermatic force in the slightly modified cell-tissues of the parent, and to be a modification of the same gemmiparous faculty as that to which the previous multiplication of the nutrient form of polype and the compound character of the whole was due.

The development of the true ova and the reproduction of the spermatic force in the ordinary form of spermatozoa seem to be the last act of the free medusoid individuals which are liberated from the *Coryne*, *Syncoryne*, and certain species of *Campanularia* and *Tubularia;* and the hydriform polype which results from the development of such ovum, together with the organically connected colony of such, developed by successive gemmation, and bearing the name of *Coryne*, *Campanularia*, &c., are larval forms, procreating parthenogenetically, and answer to the larval vesicles developing the cercarioïds which ultimately change into the generative forms of trematode entozoa. With regard to those numerous species of *Sertularia* (e. g. *S. Polyzonias*, *abietina*, *rosacea*, *pumila*, *halecina*, *Beanii*, *uber*, Dal., *argentea*, *antennina*, *ramosa*, *thuia*) and of *Plumularia* (e. g. *Pl. falcata**, *pinnata*), in which the ovicapsules give issue to planulæ, subsequently transformed into sertularian polypes, their genetic cycle is of a more simple character; the germinal basis of the planula must be viewed as an ovum impregnated by the spermatozoon developed in the sperm-capsules of the males above described.

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* CXIII. p. 28. tab. vi. f. 14.

† CXIV. p. 68. tab. ii. f. 5.

The *Anthozoa* (*figs.* 63-67.), or polypes of the second great class, characterised by a distinct abdominal cavity in which their simple digestive sac is suspended, constitute the most numerous and important part of the whole race, and include the largest individuals. They are principally the inhabitants of the warmer or tropical seas.

They are subdivided chiefly according to the number and structure of their oral tentacula. Most of the species have only eight of these radiated prehensile organs: the rest have a greater number. To this latter group belong the soft-bodied and solitary species called Sea-Anemonies, or *Actiniæ*, which are common upon our own coasts.

In the Actinia here dissected (*fig.* 63.), you will see that the skin of the body, *a*, is thick and opaque: in the living Actinia, it is lubricated by a mucous secretion: it is lined by a thick stratum of muscular fibres, the disposition of which is indicated by the superficial striæ, and may be shown, in the larger Actiniæ, to be in antagonising longitudinal, and transverse or circular, fasciculi. In the middle of the circle of the tentacles, *c*, *c*, is situated the contractile and dilatable mouth, *d*, from which a short œsophagus leads to a large gastric cavity, *e*, the parietes of which are connected by a great number of membranous vertical folds, *g*, *g*, with the external wall of the body. The tentacula are beset with numerous dart-cells: they are tubular, are perforated at their free extremity, and communicate with the interspaces, *k*, of the mesogastric lamellæ, *g*. They absorb the sea-water into these spaces, and are elongated by the injection of that water into their interior. The extended surface of the abdominal cavity is beset with innumerable minute cilia, through the action of which it is bathed by a constant current of the admitted medium of respiration, the sea-water, mixed with the chyle from the stomach. These respiratory streams pass from one compartment to another by the orifices marked *g′*, *g′*: the arrows show their direction in the opened tentacule, *h*.

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* The ciliated character of the embryo, and its locomotive power, settlement and metamorphosis into the *Plumularia* were first discovered, and are beautifully described by Dr. Grant, in CXI*., who calls the embryo "ovum."

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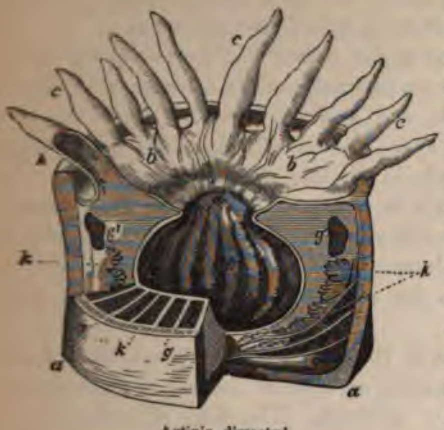

Actinia, dissected.

The ova are formed within the mesogastric folds: beneath which are situated an equal number of bodies composed of convoluted tubes which contain sperm-cells and spermatozoa, demonstrating the androgynous nature of the Actinia. The impregnated ova are developed into ciliated gemmules in the abdominal reservoir of sea-water: they sometimes enter and distend the hollow tentacles; then make their way by the small inferior aperture of the stomach into that cavity, and finally escape by the mouth of the parent.

Many of the large actiniform polypes of the tropical seas combine with a structure which is essentially similar to our own sea-anemonies*, an internal calcareous axis or skeleton, which, penetrating the interior of the mesogastric folds, presents the lamellated and radiated structure recognisable in the enduring support of the large *Fungiæ* and in the polype-cells of the skeletons of the *Caryophylleæ*, *Madreporæ*, &c. This skeleton consists of carbonate of lime, which in the *Madreporinæ* is in the condition of organised corpuscles compacted into a closely reticulated mass, on a basis of gelatinous matter. This animal constituent exists in such a proportion in some *Caryophylleæ* (*C. sinuosa*, e. g.) as to preserve the form and in some degree the foliated character of the skeleton after solution of the earthy part in acid.†

The species of polypes which take the most important share in the fabrication of the coral islands and reefs belong to the present group; and have essentially the organisation of the sea-anemony, which has just been described: but those of the genera *Madrepora* proper, *Astræa*, and *Gemmipora* have not more than twelve tentacles.

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* CXXII. p. 176. pl. viii.

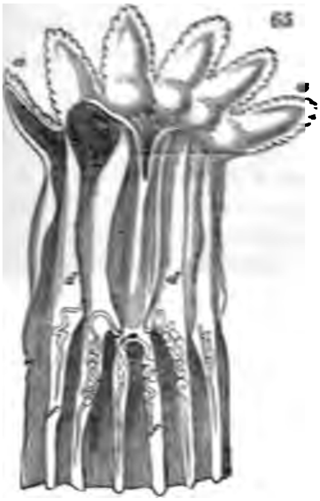
† See Prep. No. 82. c.

64

Corallium rubrum.

To the eight-armed division of the anthozoic Polypes belong those species which have an internal ramified calcareous, or flexible, or jointed axis, e. g. as the red coral, (*fig.* 64, *c*), the gorgonia, and the isis. To this division likewise belongs our common *Lobularia digitata*, or "dead-man's-toes," in which the hard axis is wanting; and the phosphorescent Sea-pens, the *Veretillum*, and other *Pennatulidæ*, in which it is in detached pieces. In all this division the polypes, *a*, are retracted into the soft enveloping tissue, *b*, not into calcareous cells.

These examples of the compound Anthozoa differ from the compound Hydrozoa in having an internal instead of an external skeleton. The body of each polype (*fig.* 65.) is relatively longer than in the *Actiniæ*; the prehensile tentacles (*a, a*) are broad and pinnate, or with scolloped margins. At the centre of their base is situated the mouth (*b*), which leads to a straight membranous alimentary cavity, fixed by vertical septa (*d, d*), called mesogastric folds, to the external integument: which septa are continued down the general visceral cavity. The digestive canal communicates with this cavity by a small orifice (*e*), at its inferior part. Sea-water passes, probably with chyle, through this aperture, to circulate over the extended ciliated surface of the abdominal cavity and the interior of the tentacles. The hepatic cells of the gastric parietes present a yellowish colour in *Alcyonium*, and a brown colour in *Veretillum*.



Polype of the *Alcyonidium elegans*, dissected and magnified.

The contractile power of both the Polypes and of their common fleshy base in the softer compound kinds is considerable. In the *Alcyonidium* the lower half of the polypary is of a firm coriaceous texture, the upper half is softer and divided into branches, the summits of which are crowned with polypes of the structure shown in *fig.* 65. These polypes, when touched, not only shrink into their fleshy fossæ, but the whole of the soft part of the polypary is contracted and withdrawn into the harder basal portion.* Mr. Darwin relates of the *Virgularia*—a long and slender kind of sea-pen, which he saw in vast numbers projecting like stubble above the surface of the muddy sand—that when touched or pulled they suddenly drew themselves in with force, so as nearly or quite to disappear. The slender calcareous axis supporting the fleshy beds of the polypes of this sea-pen becomes softer and bent towards its base, and the elasticity of this part contributes, with the expansion of the irritable tissue, to enable the *Virgularia* to rise again through the mud.†

Ovaria and sometimes tortuous filamentary secreting organs (*f*) analogous to the testes in the Actinia, are developed from the mesogastric folds in the chylaqueous cavity. In the anthozoic polypes of the red coral most of the individuals are androgynous, and present both the ova and the spermatozoa; but a few instances occur in which some polypes develope only the one kind of generative product, and others the other kind. In those singular forms of compound polypes, called *Pennatulæ*, or sea-pens, the ova are found in the pinnæ or branches of the common stem or axis of the polypes. But groups of individuals have been found in which only the sperm-sacs are developed.‡ In the *Veretillum* a delicate network of vessels conveys the nutrient fluid prepared by each polype to the common connecting parenchyme of the entire compound animal.

In the *Gorgonia verrucosa* Cavolini states § that the ova, which are developed in an ovarium situated at the base of each polype, doubtless in the mesogastric folds, are discharged by eight small pores which open between the bases of the eight tentacles. The ova escape as ciliated "planulæ" of an ovoid form, which emerge from the ovarian pore with their small end foremost, then turn and swim with the great end foremost. In the month of June a Gorgonia, six inches in height, discharged ninety such larvæ in the space of an hour. They first rose spirally towards the surface of the water, then swam horizontally. They have the same property as the ciliated planulæ of the marine Hydrozoa of changing their form by contraction of their tissue, a property which the ciliated zoospores of sponges and algæ do not possess. When the larvæ of the Gorgoniæ rested they attached themselves to the vessel containing them by their larger end. The ciliated embryos of the *Caryophyllia calycularis* are also discharged by small apertures at the basal interspaces of the tentacles of each polype. ‖ They are of a deeper red colour than those of the *Gorgonia*, have the same locomotive power, and show the same homogeneous granular texture when broken up under the microscope. In the *Pennatula phosphorea* the ova, of the size and form of poppy seeds and of a yellow colour, are found at the back part of the pinnæ. In *Virgularia mirabilis* the small, round white ova are seen in spring, ranged in a double transverse row under each of the lateral fleshy expansions, forming external projections; but as the embryo acquires its ciliated superficies and yellow colour, it advances slowly into the body of the polype beneath which it was developed, and begins to manifest contractions of its tissue and revolving movements, by which it escapes from the mouth of the polype and swims slowly away.* This locomotive faculty is much abridged, if not wholly lost, when the animal has acquired its mature form and begins to propagate by continuous gemmation. The Pennatulæ do not swim, as has been supposed, by the movements of the pinnæ, but move languidly; most of the family remain at the bottom; and the *Virgulariæ* and *Pavonariæ* have one end stuck deeply in the sand or mud, into which they can retract themselves. In the *Lobularia* the ova are formed and matured in the longitudinal mesogastric folds of the polypes.† Ellis‡ has well represented them, in groups of from five to eight in each of the canals below the polypes, and also the larvæ in their passage through the transparent bodies of the polypes. When the larvæ have acquired their ciliated surface and red colour they become detached from the mesogastric folds, and work their way slowly through the polypes when the bodies of these are expanded and distended with water. Certain individuals, or groups of individuals, of the *Lobularia digitata* have been found to develop only sperm-sacs and spermatozoa.§

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* CXXIV. p. 2.

† CXXIX. p. 99.

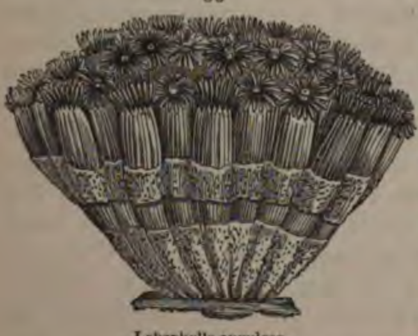
‡ CXV. p. 101.

§ CVI. pp. 47. 50. tab. iv. figs. 7—10, and 13—15.

‖ CVI. p. 56.

The fleshy substance of the *Actiniæ*, *Lobulariæ* and *Alcyonia* is strengthened by numerous minute calcareous spiculæ. Analogous spiculæ, but of varying and characteristic forms, strengthen likewise the fleshy crust of the red corals, jointed corals, and Gorgoniæ; but to these spiculæ is superadded the internal branched axis, which, according to its composition and structure, characterises the different genera of this group. The spiculæ of the cortical part consist principally of carbonate of lime, like the denser skeletons of the *Madreporidæ*, *fig.* 66, with which they

66



Lobophylla angulosa.

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* CXVIII. p. 350.

† CXIX. p. 104.

‡ CXX. pl. xx.

§ CXV. p. 101.

are homologous; but the axis *fig.* 64, *c*, consists of a substance analogous to horn, hardened by phosphate of lime with only a slight trace of carbonate of lime. In one genus of Anthozoa, the external position of the skeleton which characterises the hydriform compound polypes is repeated, viz. in the *Tubipora;* but the organisation of the polypes, protected by the crimson pipes of this beautiful coral, *fig.* 67, is essentially the same as in the *Alcyonium*, *Gorgonia*, and *Pennatula.*

67

Tubipora musica.

The most important productions of the apparently insignificant race of Polypi are the accumulations of the calcareous skeletons of the Anthozoa, which form the coral islands and reefs; — the dread of the navigator, — the admiration of the lover of the picturesque, — the subjects of the closest and most interesting speculation to the naturalist and geologist.

That masses of rock many leagues in extent should be founded in the depths of the ocean, and built up to the height of hundreds of feet, by minute, frail, gelatinous animalcules, is indeed a phenomenon calculated to stagger the unversed in zoological science, and which has demanded the repeated observation of the most accomplished naturalists and enlightened voyagers to render intelligible.

These zoophytic productions are classified under three heads: "atolls," "barrier reefs," and "fringing reefs." The term "atoll" is the name given to the coral-islands, or lagoon-islands by their inhabitants in the Indian ocean. An atoll consists of a wall or mound of coral rock (*fig.* 70. *r′*, *r″*), rising in the ocean from a considerable depth, and returning into itself so as to form a ring, with a lagoon, or sheet of still water (*n*), in the interior. The wall is generally breached in one or more places, and when the breach is deep enough to admit a ship, the atoll affords it a convenient and safe harbour. The outer side of the reef usually sinks to a depth of from two to three hundred fathoms, at an angle of forty-five degrees or more: the internal side shelves gradually towards the centre of the lagoon, forming a saucer-shaped cavity, the depth of which varies from one fathom to fifty. The summit of the exterior margin of the reef or wall is usually composed of living species of *Porites* and *Millepora.* The *Porites* form irregularly rounded masses of from four to eight feet broad, and of nearly equal thickness; other parts of the reef are composed of thick vertical plates of the *Millepora complanata* intersecting each other at various angles, and forming an exceedingly strong honeycombed mass. The dead parts of these calcareous skeletons are often cemented over with a layer of the marine vegetable called *Nullipora*, which can better bear exposure to the air.

This strong barrier is well fitted to receive the first shock of the heavy waves of the fathomless ocean without; and, what at first appears surprising, instead of wearing away at its outer edge, it is here only that the solid reef increases. The coral animals thrive best in the surf occasioned by the breakers. Through this agitation an ever-changing and aërated body of sea water washes over their surface, and their imperfect respiration is maintained at the highest state of activity. Abundant animalcules, and the like objects of food, are thus constantly brought within the sphere of the tentacula of the hungry polypes. Their reproductive gemmules are rapidly and extensively dispersed amongst the crevices of the calcareous mass.

By the force of unusual storms this outer reef is occasionally breached, and huge masses are torn off and driven towards the lagoon, where they form an inner barrier or reef. The broken surface becomes the seat of attachment of the young of the neighbouring corals, the successive generations of which, by the rapid growth and development of their calcareous skeletons, soon repair the damage of the storm. The masses of broken coral thus driven inward towards the lagoon, accumulate in time to the height of some feet above high water. These fragments are mixed with sand and shells, and form a favourable soil for the development and growth of vegetables, as cocoa palms, the large nuts of which may be borne hither by currents of the ocean, from Sumatra or Java, 600 miles distant. Turtles likewise float to the nascent island, browse on the sea weeds which grow in the lagoon, and breed there. Numerous species of fish and shellfish flourish in the same still water, which abounds with animal life. Man comes at last and takes possession of the island; and the cocoanut, the turtle, and the fish afford him abundant and wholesome food.

But you will ask how he supplies himself with that necessary of life, fresh water? This is obtained in a very simple and unexpected manner from shallow wells, dug in the calcareous sand, which ebb and flow with the tides, yet are almost wholly free from the saline particles of the ocean. Some have supposed that the sea water lost its peculiar salts by infiltration through the calcareous mass. Mr. Darwin thinks that it is derived from the rain water, which, being specifically lighter than the salt, keeps floating on its surface, and is subject to the same movements: howsoever this may be, the fact is certain. A fit and convenient abode for the human species is fabricated by the action of the feeble, gelatinous polypes, and a wild and almost boundless waste of waters is enlivened by oases which navigators have described as earthly paradises.

A barrier reef (*fig.* 69. *r′, r′*) is essentially similar to the atoll or coral-island. It runs parallel with the shores of some larger island or continent; separated, however, from the land, by a broad and deep lagoon channel (*n, n*), and having the outer side as deep and steep as in the Lagoon Islands. Here likewise the skeletons of the Zoophytes, of which the reef is composed, are found on the outer precipitous wall as deep as sounding line can reach.

The third class of coral productions which Mr. Darwin terms "fringing reefs" (*fig.* 68. *r, r*), differ from the barrier reefs in having a comparatively small depth of water on the outer side, and a narrower and shallower lagoon channel between them and the main land.

These differences in the characters of the wonderful fabrications of the coral animalcules are explicable by the following facts in their physiology. The animals of the *Porites* and *Milleporæ* cannot exist at a greater depth than twenty or thirty fathoms; beyond this the stimuli of light and heat derived from the solar beams become too feeble to excite and maintain their vital powers. On the other hand, their tissues are so delicate, that a brief direct exposure to the sun's rays kills them; and unless they are constantly immersed in water or beaten by the surf, they cannot live. Thus, in whatever position the calcareous skeleton of a Madrepore or Millepore may be found, it is certain that it must have been developed within thirty fathoms of the surface of the ocean. If it coats the summit of the lofty mountains of Tahiti *, it must have been lifted above the sea by the elevation of the rock on which it was originally deposited. If it is brought up from the depth of 200 or 300 fathoms, as at Cardoo Atoll or Keeling Atoll, it must have been dragged down to that depth by a gradual subsidence of the foundation on which the living madrepore once flourished. It is by these movements of upheaval and subsidence of the earth's crust, that Mr. Darwin explains the different forms which characterise the extraordinary productions of the coral animals. *Atolls*, according to this author, rest on land which has subsided, and part of which was once dry. *Barrier reefs* indicate the islands or continents, which they encircle, to be the remains of land now partly submerged, and perhaps in progress towards final disappearance. *Fringing reefs*, on the contrary, indicate either that the shores are stationary, or that they are now rising, as in most of the Sandwich Islands, where former reefs have been raised many yards above the sea.

Elizabeth Island, which is eighty feet in height, is entirely composed of coral-rock. The coral animals, thus progressively lifted

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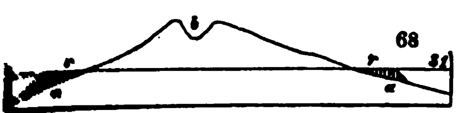
* Mr. Stutchbury here found a regular stratum of semifossil coral at 5000 and 7000 feet above the level of the sea.

[illegible] their element, are compelled to carry on their operations more and more remote from the former theatres of their constructive [illegible] but cannot extend deeper than their allotted thirty fathoms; the direction of their submarine masonry is centrifugal and descending. Where the land that supports them is, on the contrary, in progress of submergence, they are compelled to build their edifices progressively higher and in a narrower circuit; in other words, the direction of their growth is centripetal and ascending. The terms ascending and descending, of course, only here apply to the relation of the coral-builders to the unstable land, not to the level of the unchanging sea.

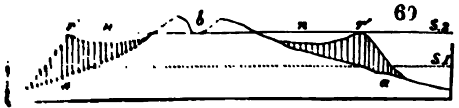
The formation of an atoll by the upward growth of the corals during a gradual sinking of the land forming their supporting base is illustrated by these diagrams from Mr. Darwin's work.* Figure 68. represents the section of an island (*a*, *b*), surrounded by a fringing reef, *r*, rising to the surface of the sea, s. 1.



68

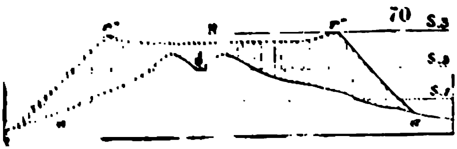
Fringing Reef.

As the land sinks down, the living coral, bathed by the surf on the margin of the reef, builds upwards to regain the surface. But the island becomes lower and smaller, and the space between the edge of the reef, *r*, and the beach proportionately broader. A section of the reef and island, after a subsidence of several hundred feet, is given in figure 69. The former living margin of the reef, *r*, is now dead coral, dragged down to depths at which the polypes cease to exist; but their progeny continue in active life at *r'*, now the margin of a barrier reef, separated by the lagoon channel *n*, from the remnant of the land *b*. Let the island go on subsiding, and the coral reef will continue growing up on its own foundation, whilst the water gains on the land, until the highest point is covered, and there remains a perfect atoll, of which figure 70. represents a vertical section. In this diagram *r''* is the living and growing outer margin of the encircling reef, and the lagoon channel is now converted into the calm central lake *n*, of the atoll. Thus by the process of subsidence



69

Barrier Reef.



70

Atoll.

the fringing reef (*fig.* 68.) is converted into the barrier reef (*fig.* 69.), and this into the atoll (*fig.* 70.).

If the movement of the land should now be reversed, and the level of the sea be again brought back by elevation of the island, to the line (s. 1. *fig.* 70.), an island apparently composed exclusively of coral rock, like Elizabeth Island, would be the result.

The prodigious extent of the combined and unintermitting labours of these little world-architects must be witnessed in order to be adequately conceived. They have built up a barrier-reef along the shores of New Caledonia for a length of 400 miles, and another which runs along the north-east coast of Australia 1000 miles in extent. To take a small example, a single atoll may be 50 miles in length by 20 in breadth; so that if the ledge of coral rock forming the ring were extended in one line it would be 120 miles in length. Assuming it to be a quarter of a mile in breadth, and 150 feet deep, here is a mound, compared with which the walls of Babylon, the great wall of China, or the pyramids of Egypt, are but children's toys; and built too amidst the waves of the ocean and in defiance of its storms, which sweep away the most solid works of man.

The geologist, in contemplating these stupendous operations, appreciates the conditions and powers by which were deposited in ancient times, and under other atmospheric influences than now characterise our climate, those downs of chalk which give fertility to the south coast and many other parts of our native island. The remains of the corals in these masses, though similar in their general nature, are specifically distinct from the living polypes which are now actively engaged in forming similar fertile deposits on the undulating and half submerged crust of the earth, washed by the Indian and Pacific oceans.* Again, those masses of limestone rocks which form a large part of the older secondary formations, give evidence, by their organic remains, that they too are due to the secretions of gelatinous polypes, the species of which perished before those that formed the cretaceous strata were created. As the polypes of the secondary epochs have been superseded by the *Porites*, *Milleporæ*, *Madreporæ*, and other genera of calcareous Anthozoa of the present day, so these, in all probability, are destined to give way in their turn to new forms of essentially analogous Zoophytes, to which, in time to come, the same great office will be assigned, to clothe with fertile lime-stone future rising continents.

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* See the admirable description of the corals of the chalk by Mr. Lonsdale, in CXXI. pp. 237—324.

LECTURE VIII.

BRYOZOA.*

If a deeper and truer insight into the structure and vital properties of the low-organised, ramified, composite, hydriform polypes, which, like little trees adorned with polypetalous flowers and supporting their annual crop of deciduous fruit or seed-capsules, deceived such clear-sighted observes as Tournefort and Ray as to their real nature, and were classed by them with vegetables; if organised beings, so obviously like plants in external form and in some of their most conspicuous changes, can be proved by the anatomist to belong unequivocally to the Animal Kingdom, without the determination being vitiated or obscured by any real or essential vegetable character; — if the calcareous masses of Madrepores and Millepores, classed by Boccone and Guison as species of minerals, and which once were the subjects of curious speculations on the growth of stones, have been proved by the recognition of the more complicated organisation of the polypes which they support, to be the products of the vital actions of such polypes, and as essentially a part of those animals as the skeleton of a man is a part of his body; — still more does the anatomical structure of the third division of polypes prove how inadequate is a superficial survey of an organised being to lead to true notions of its nature and affinities. The *Bryozoa*, which coat, as with a delicate moss, fuci, shells, or other marine productions, or which rise in dendritic forms, like the hydrozoic corallines, with which they were associated by Ellis†, with which they would equally have passed for plants with Ray, are, perhaps, the most striking examples of how complicated an animal structure may be masked by mere outward form.

A locomotive organised being must possess an internal digestive store-room; but the converse of the proposition does not hold good, — a digestive cavity does not imply the powers of locomotion.

The Bryozoon has not merely a digestive cavity, like the Hydra and the Actinia; it has not merely the characteristic mouth and radiated prehensile organs for the capture of living prey; but it has also an œsophagus for deglutition, an intestine for the separation of the nutrient chyle, and a distinct external outlet for the indigestible refuse of the food: it may possess a stomach with strong muscular walls and a dentated lining for trituration, and a second stomach with glandular walls for digestive solution or chymification, and thus present an alimentary canal as complicated and as highly elaborated as in the bird. Yet the microscopic polypes which manifest this high condition of the digestive apparatus are fettered to the spot, where, as ciliated gemmules, they finally rested after their brief early locomotive stage: the complex digestive apparatus is developed for the service of an organised being as immovable as the plant which is rooted in the soil. But we shall, hereafter, meet with animals of higher grade of organisation than the Bryozoic polypes, as e. g. the Barnacle, the Oyster, and the Spondylus, which are equally fettered to the spot on which they grow, and which more strikingly demonstrate how secondary a character of animal life is mere locomotion.

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* Ehrenberg, CXXXIII. (1827). *Polyzoa.* Thompson, CXXIII. p. 92. (1830.)
† *Ciliobrachiata*, Farre, XXXV.

† This accurate observer, however, places many of the *Bryozoa* in a family, as "cellulous corallines," distinct from the "vesiculated" and "tubular" corallines, XCVII. p. 33.

The complicated and characteristic condition of the alimentary canal in the Bryozoa was discovered independently and nearly about the same time, by Ehrenberg*, by Audouin and Edwards†, and by Dr. V. Thompson.‡ The ciliated structure of the arms was observed by Steinbuch § and Dr. Fleming.‖ The ciliated larvæ, and their place of development, have been well described in the *Flustra carbesia* by Dr. Grant.¶ All these observations have received a welcome confirmation, and many highly interesting facts in the organisation and properties of the Bryozoa have been added by Dr. A. Farre; a careful perusal of whose admirable Memoir in the Philosophical Transactions for 1837**, will amply repay the reader.

Most of the Bryozoa are microscopic; but, being composite or aggregated animals, they sometimes form sufficiently conspicuous masses. The most familiar and common species constitute the substance called sea-mat (*Flustra*), which incrusts, by its little hexagonal cells, as by a delicate mosaic pavement, sea-weed, shells, and other marine bodies. The calcareous sea-mat is called *Eschara*. Some species (*Halodactylus*) rise from their surface of attachment and form amorphous masses, like sponge; others (*Vesicularia*, *Valkeria*, *Serialaria*, *Cellularia*) are regularly and delicately ramified, like the little hydriform corallines.

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* CXXXIII. Bryozoa "ore anoque distinctis tubo cibario perfecto."

† CXXIV. p. 13.

‡ CXXIII.

§ CXXV. p. 89.

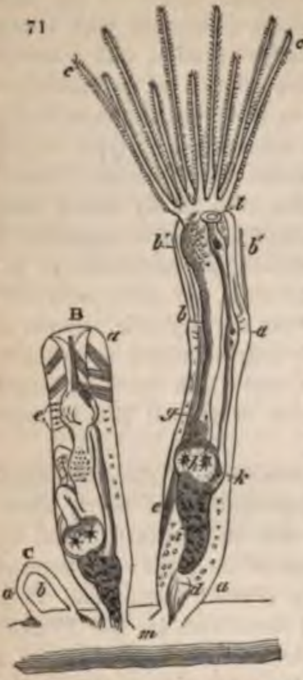
‖ CXXVI. p. 488. pl. xv. fig. 1. *c.*

¶ CVIII. p. 116.

** XXXV. p. 387. plates xx. to xxvii.

Each polype presents an oblong depressed, or elongated and cylindrical figure, and is protected by a dense integument in the form of a cell or case (*fig.* 71, *a*, *a*), to the mouth of which is attached a sac (*b*, *b′*) composed of very delicate and flexible membrane. This constitutes the upper or anterior integument of the polype when it is protruded, and is reflected, like the inverted finger of a glove, into the firmer portion of the cell when the polype is retracted, as at *B*. In general the integument forming the firm cell is of a horny texture; but in the *Escharæ* it is hardened by the deposition of particles of carbonate of lime in the organised animal basis; so that the external skeletons of the Bryozoa offer analogous conditions to the cartilaginous and bony states of the internal skeletons of fishes. The mouths of the cells in *Eschara* and *Cellepora* are provided with a moveable lid with a pair of muscles for closing it, when the polype is retracted.* In the *Tendra zostericola* there is instead of a solid operculum a large flat fleshy ring, fixed to the walls of the cell by four muscular fasciculi: four other bundles attach the opercular ring to the border of the opening of the cell: the movements of this muscular mechanism are both curious and beautiful when the little polype protrudes from or draws back into its cell.

71



Polypes of a Bryozoon, magnified, × 80.

In the cylindrical Bryozoa, as the *Bowerbankia*, the flexible part of the integument consists of two portions; the lower half being a simple continuation of the cell; the upper one consisting of a cylindrical series of setæ (*b′*), connected together by an extremely delicate and elastic membrane, permitting a certain extension of the cylinder, which, at the same time, supports and allows free motion to the upper part of the body in its expanded state. The mouth of the polype is situated at this extremity of the body, and is surrounded by a radiated series of slender, ciliated tentacula (*c*), eight, ten, twelve, or more in number, according to the genus.

The muscular system is developed in the present highly organised class of polypes, in the form of distinct groups of fibres. Their arrangement, and the actions by which they effect the protrusion and retraction of the polype, are minutely and clearly described by Dr. Farre.* The retractor muscles form two series, one acting upon the alimentary canal, and the other upon the flexible part of the cell. One series rises from the bottom of the cell, and is inserted about the base of the stomach (*d*); the other (*e*, B) arises from the opposite side of the bottom of the cell, and passes upwards to be inserted near the base of the tentacula. The muscles which retract the flexible integument and the setose operculum arise near the upper margin of the cell (between *e* and *a*, B), and are disposed in six fasciculi, three of which act upon the membrane, and the other three upon the bundle of setæ by which it is crowned. When the animal is retracted, the setæ, which are drawn in after the tentacula, converge and form a kind of defensive operculum. The œsophagus and intestine are bent into folds: their parietes are contractile.

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* CXXVII. p. 25. pl. i. fig. 1. *e* and *i*.

The protrusion of the animal is effected, partly by the action of short transverse muscular filaments (*e*), which tend to compress the inclosed viscera, and partly by the action of the alimentary canal itself. The bundle of setæ (*fig.* 72., 1., *a*, *b*, *c*) first rises out of the cell (*c*), and is followed by the rest of the flexible integument (ib. 2.): the tentacula next pass up between the setæ (*d*), and separate them; the folds of the œsophagus and intestine are straightened, and when the act of protrusion is completed, the crown of tentacles expands and their cilia commence vibrating (*fig.* 71. *c*).

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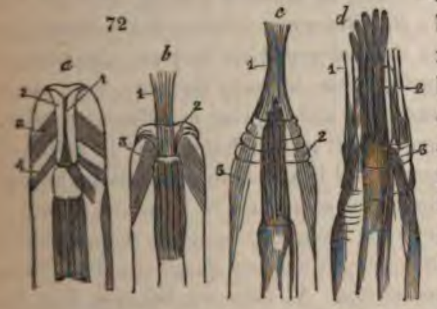

Unfolding of the operculum and upper part of the body, in four stages. *Bowerbankia.*

The advantage to Physiology of the researches of the comparative anatomist in the minute forms of animal life, is often very great, in consequence of the favourable conditions which the transparency of the integument, and the distinctness of the contained parts of such animalcules, afford for the direct observation of some of the most recondite and important vital actions. As regards the *Bryozoa*, the muscles are, as it were, naturally dissected or separated into their component filaments. Each filament generally presents a small knot upon its middle part: this is most apparent, being thickened when the filament contracts, at which time the whole filament is obviously thicker. When the action ceases and the filament is relaxed, the distance between its fixed points being diminished, as happens to the longitudinal fibres when the polype is retracted into its cell, such fibre falls into undulations. The thickening of the muscular fibre in the act of contraction, and its folded state when it relaxes, before the antagonising muscles have restored the extremities of the contracted fibre to their ordinary distance, has been observed in other low organised animals, as small Filariæ.* The higher organised subjects selected by MM. Prevost and Dumas, were less favourable for this delicate experiment, and they consequently mistook the zig-zag relaxation of the muscular fibre for its act of contraction. In *Notamia* and *Anguinaria* a faint striation has been observed on the ultimate fibre. Minute appendages called "pedicellariæ" are fixed to the cells in most Bryozoa. Ellis, who has figured them in the *Cellularia avicularis*, compares them to "a bird's head with a crooked beak, opening very wide:" † they consist of a fixed and a moveable nipper, like a crab's claw, the latter being worked by muscles arising from the interior of the fixed portion. In the *Retepora cellulosa* the pedicellariæ resemble a pair of pincers: in the *Telegraphina* they are simple one-jointed spines. The entire pedicellariæ, in many Bryozoa, have oscillatory movements, more or less rapid and regular, in different species. The removal of the polype from the cell to which they may be attached does not affect these movements: and if a chelate pedicellaria be cut off, its moveable nipper continues for some time to open and close.‡

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* XXXV. pp. 394—398.

Dumortier describes two nervous ganglions near the mouth of the *Plumatella cristata*, and Nordmann similar ganglions in *Plum. campanulata* and *Tendra zostericola*. V. Beneden believes that he has traced an œsophageal nervous collar in the *Alcyonella* §; but Dr. Farre was unable to satisfy himself as to any definite trace of a nervous system in the marine *Bryozoa*, which he has so ably anatomised. The reaction of stimuli upon the contractile fibre was, however, a striking phenomenon in these. The animal retires into its cell on the slightest alarm, and refuses to expose itself to water which has become in the least degree deteriorated. Dr. Farre has observed the creeping of a very small animalcule over the top of one of the closed cells to be followed instantly by the shrinking of the soft parts beneath. But the nervous system is indicated in these little polypes by something more than reflex phenomena: they seem to exercise a certain caution before emerging from their cells. One or more of the tentacles have been seen to be protruded and turned over the side of the cell, as if to ascertain the presence or absence of an enemy.*

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* CXXVIII. p. 261.

† XCVII. p. 36. pl. xx. A.

‡ CXXIX. p. 201.

§ Cited in XXIV. p. 34.

I must now proceed to describe these tentacula (*c*, *c*), which are the means whereby the *Bryozoa* obtain their food. They differ considerably from the corresponding tentacula in the *Hydrozoa* and *Anthozoa*, in being stiffer and provided with vibratile cilia. These cilia are arranged on opposite sides of the tentacle, along which sides they occasion, by their active vibration, opposite currents of the surrounding water: they vibrate, not in the plane of the arms, but at right angles with it, and bend obliquely in the form of a hook.† In some species a few fine hair-like processes, which are motionless, project from the back of the tentacula. The action of the tentacular cilia appears to be under the control of the animal, and they are sometimes seen completely at rest. The arms are tubular throughout, and have an aperture at each extremity. The ring upon which they are set forms a projecting edge around the mouth. The particles of food are carried down the inner surface of each arm, and the mouth and pharynx expand to receive such as are appropriate, as if by an act of selection. The rejected particles pass out between the bases of the tentacula, or are driven off by the centrifugal currents.

In the fresh-water *Alcyonellæ* and *Cristatellæ* the mouth is provided with a tongue-shaped process covered with vibratile cilia. Nordmann describes each of the eight ciliated tentacles in the *Tendra zostericola* as being traversed by two longitudinal canals.‡

The pharynx in all Bryozoa is less dilatable than is the mouth of the Hydra or Actinia. The constriction of the pharynx, by which the food is driven into the œsophagus, is a very well-marked action. The parietes of the gullet consist of three layers of which the two outer ones seem to be muscular, and are thick in *Tendra:* the inner layer is a thin epithelium over which a network of delicate canals in a polygonal pattern is spread. The cardiac orifice (*fig.* 71, *g*) seems to project into the œsophagus upon a valvular prominence; it opens into a small globular cavity (*h*), which has the construction of a gizzard: the interior of this cavity is lined by a strong epithelium, the cells of which project into the cavity like pointed teeth, and the food is subject to comminution in this cavity. With the gizzard is associated, as in birds, a distinct glandular compartment of the stomach (*i*); but this is situated between the gizzard and intestine, not between the gizzard and œsophagus: its walls are studded with cells or follicles filled with a deep brown secretion, which may be regarded as hepatic follicles. The intestine is continued from a distinct pyloric orifice (*k*), which is situated at the upper part of the glandular stomach near the gizzard. This orifice is surrounded by vibratile cilia. The food is frequently regurgitated into the gizzard, and, after having undergone additional comminution, is returned to the stomach. Here it is kept in constant agitation, and the particles pass by a rotatory action from the pylorus into the intestine. The indigestible particles are there formed into little pellets, which are carried rapidly upwards to the anal orifice (*l*), and after being expelled, are immediately whirled away in the current produced by the ciliated tentacula. The intestine in *Cristatella* is short as compared with that in *fig.* 71., and in *Vesicularia*. The action of the sphincter may be seen when the fæces are expelled.

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* XXXV. p. 414.

† XXXV. p. 411.

‡ CXX. p. 187.

A small filament, conjectured to be tubular, which passed from the base of the glandular stomach to the common stem (*m*) supporting the cell of the polype, is the only trace of the nutrient or vascular system which Dr. Farre could detect. When the common stem of a ramified Bryozoon is cut across, it seems to be nearly homogeneous, and does not present that obvious distinction between hard and soft parts, nor the canal with circulating particles, which are observed in the stems of the compound Hydrozoa. Yet it can scarcely be doubted but that nutrient currents must traverse the common connecting organic medium or stem of the Bryozoa, both for its own support and growth, and for the supply of the means of growth to the young animals (*C*) which are developed from it by the process of gemmation.

The function of respiration must be referred to those parts of the body which are provided with the means of effecting a constant renewal of the surrounding oxygenized medium upon its surface. In the ciliated tentacula, whose currents, Dr. Farre observes, seem much beyond what is necessary to afford a sufficient supply of food, we most probably perceive the principal respiratory as well as prehensile organs. There is a regular and uninterrupted stream of fluid in a given direction in the abdominal cavity: whence it extends into the canals of the tentacula. Siebold regards this movement as being due to the ciliated epithelium which he detected lining the abdominal cavity of *Cristatella mirabilis* and *Alcyonella stagnorum*. Van Beneden indicates a series of pores at the bases of the tentacula in the Alcyonella, which he calls "bouches aquifères," conceiving that by them water is admitted into the abdominal cavity.*

The individuals of the Bryozoa are multiplied by two processes of generation; the one by gemmæ or buds from the common stem or polypary, which appears to be uninfluenced by season, and which increases the size of the aggregate mass of the Bryozoon; the other by the liberation of the young, usually in the form of locomotive ciliated larvæ, which takes place at certain seasons, generally in spring.

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* CXXXIV. p. 222.

In the *Flustra* the gemmæ are developed from the cells of the pre-formed individuals; but in those Bryozoa which have connecting stems the buds arise from the stem. They are at first homogeneous; then a distinction may be observed between the cell (*fig.* 71, C, *a*) and the visceral contents (*b*); afterwards the tentacles may be discerned, which are at first short and stumpy; finally, the cavity, walls, and divisions of the alimentary canal become distinguishable.

In regard to the generation by locomotive larvæ, these are, doubtless, originally developed from fertile ova.

Certain phenomena have been observed in the Bryozoa which justify the belief that the individual polypes are male and female. Dr. Farre has figured a specimen of the *Valkeria cuscuta* *; in which he observed a very remarkable agitation of particles in the visceral cavity, caused by a multitude of minute cercarioïds swimming about with the greatest activity in the fluid with which that cavity is filled: they consisted simply of a long slender filament with a rounded extremity, by which they occasionally fixed themselves. Similar moving filaments were not unfrequently observed in other species. On one occasion Dr. Farre observed them in a specimen of *Halodactylus*, drifting rapidly to the upper part of the visceral cavity, and issuing from the centre of the tentacula, indicating an external communication with the cavity of the body. Dr. Soulby, of Dover, informs me that he distinctly saw a stream of spermatozoa escaping, like smoke, from the terminal orifice of each tentaculum of a *Halodactylus*. The analogy of these cercarioïds with the spermatozoa discovered by Wagner in the tortuous generative tubes of the Actinia, indicates their real nature and importance in the generative economy of the Bryozoa. Van Beneden has since communicated his discovery of male and female polypes on the same polypary of the *Alcyonella;* the males are fewer than the females, and are recognizable by the conspicuous spermatozoa, formed by a testis, which holds a similar position in the male polype to that of the ovary in the female, viz. behind the stomach.†

To the same able observer we are indebted for illustrations of the development of the impregnated ova in another genus of Bryozoon, viz., *Pedicellina.* The ova are pyriform, and are aggregated like grapes in clusters by the pellucid (chorionic?) membrane in which they are enclosed (*fig.* 73., 1.); the yolk is a "germ-yolk," and has a vitelline membrane separated by a whitish fluid from the chorion. The fission of the germ-cell is followed by total cleavage of the yolk, as in 2; it next subdivides into four, as in 3; after which the formation of the germ-mass, 4, proceeds rapidly. Its surface becomes smooth, large cilia are developed from one end, which becomes marked off by a constriction from the other, as at 5. The larva escapes from the chorion under the form 6, and swims freely abroad. The ciliated margin expands, and renders that end of the larva funnel-shaped. Tubercles bud forth from the funnel, and a pedicle is developed from the opposite end, as at 7; by this the larva attaches itself, and in the course of the subsequent metamorphosis the lineaments of the parent Bryozoon soon begins to be traceable, as at 8.

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* XXXV. pl. xxiii. fig. 5.

† CXXXIV. p. 222.

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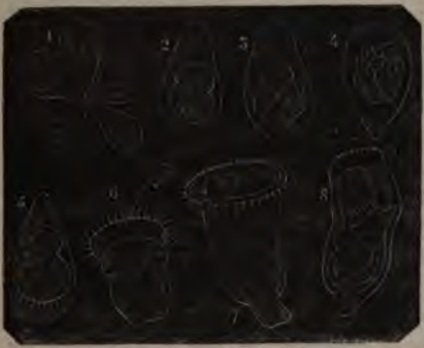

Development of Pedicellina.

The development and vital phenomena of the reproductive gemmules have been studied by Dr. Farre with much care and success in the sponge-like *Halodactylus* (*Alcyonium gelatinosum,* of Pallas). They appear in spring as minute whitish points just below the surface. If one of these points be carefully turned out with a needle, it is found to consist of a transparent sac, containing generally from four to six of the larvæ. These are of a semi-oval form, with the margin of their plain surface developed into tubercles supporting groups of vibratile cilia (*fig.* 74.).* The body presents a simple granular structure; the gemmule swims about actively by the vibration of its cilia, the motion of which seems to be under its control. They generally swim with the convex part forwards; sometimes they simply rotate upon their axis, or execute a series of summersets; or, selecting a fixed point, they whirl round

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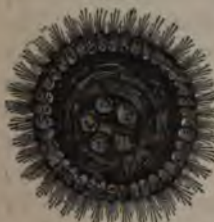

Larva of Halodactylus, from above; the cilia as when slowly acting round the margin in waves.

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* The movements of the cilia, which give the appearance of a succession of waves, have been closely analysed in XXXV. pp. 410, 411.

it in rapid circles, carrying every loose particle after them; or they creep along the bottom of the watch glass upon one end with a waddling gait: but at the expiration of forty-eight hours they attach themselves to the surface of the glass, and the rudiments of the cell may be observed.

In the *Flustra carbesia* the ova are developed between the cell and the body of the polype, which yields to, and is destroyed by, them as they are developed. They produce ovate, yellow, ciliated larvæ, which, by virtue of the contractility of their tissue and the active vibration of their cilia, escape with their small end foremost from the opening of the cell. They then, after a short term of locomotive life, settle and subside, the outline of the cell being first formed, and the polype with its tentacula, muscles, and alimentary canal being afterwards developed in a distinct small closed sac.* The embryo acquires its ciliated surface and power of contraction before it ruptures the chorion; it afterwards escapes from the parent cell. These ciliated larvæ are called "ova" in CVIII. and other writings of the same Author. Nordmann found in a Flustra of the species called *Tendra zostericola*, that spermatozoa were developed in the polypes of certain cells and ova in those of others, and that the male cell communicated by an opening with a contiguous female cell: this latter is distinguished externally by the trellis-work pattern of its upper surface, that in the male being smooth. The formation of the spermatozoa is ascribed to eight vermiform organs, which are wanting in the female polypes; but are attached near the base of the tentacula in the males.

There are a few genera of fresh-water polypes, e. g. *Alcyonella*, *Plumatella*, and *Cristatella*, which have the ciliated tentacula in the form of crescentic or horse-shoe lobes. The generative organ is a membranous band extending from the bend of the stomach to the bottom of the alimentary sac, in which are developed, according to the sex, either ova or spermatozoa: the latter in sperm-cells which succeed each other in a beaded series. The ova are usually few in number: the germinal vesicle disappears, as in the ova of the Ascaris, before the chorion is formed. This membrane is coriaceous, smooth, and brown-coloured in the elliptic compressed eggs of *Alcyonella*. The *Cristatella* has been observed to produce ova of a flattened discoid form, with their outer surface singularly beset with long bifurcated hooks like the infusorial *Xanthidia*. The young *Cristatella* undergoes its metamorphosis from the ciliated gemmule-state to the mature form of the polype in the ovum, from which it escapes by splitting it into two parts. Sometimes a second polype is developed by gemmation before this takes place; and others bud out before the colony becomes fixed: and in this free state it forms the *Cristatella mucedo* of Cuvier.

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* CVIII. pp. 116-118.

In thus tracing upwards the organisation of the animals which present the common external character of a circle of radiated oral tentacula, we have met with modifications of anatomical structure which clearly indicate three classes, and conduct us from a grade of organisation as low as that of the monad, to one as high as that of the wheel-animalcule. We have already seen that certain forms of the Rotifera, as the *Stephanoceros*, combine the external characteristics of the Bryozoa, e. g. the cell and ciliated tentacula, with an equally complicated type of internal organisation; but no rotiferous animal developes buds; the Bryozoa still retain this common characteristic of the whole race of polypi.

The Bryozoa make a still closer approximation to the compound Ascidians, which form the lowest step of the molluscous series: but in these we find the ciliated tentacles reduced to mere rudiments at the entrance of the alimentary canal; whilst the pharynx, or first division, is disproportionately enlarged, and, being highly vascular, and beset with vibratile cilia, performs the chief part of the respiratory function. No compound Ascidian, moreover, quits the ovum, as a gemmule swimming by means of cilia either generally diffused, or aggregated on special lobes after the type of the rotifer; and no Bryozoon quits the ovum, in the guise of a cercarian, to swim abroad by the alternate inflections of a caudal appendage.

The metamorphoses which the Bryozoa undergo are essentially of the same type as those of the lower Polypi: the embryo developed from the ovum is an oval, discoid, or subdepressed body, with a general or partial ciliated surface, by which it enjoys a brief locomotive life after its liberation from the parent: the exceptions to this rule being few, and confined to some fresh-water forms, e. g. *Alcyonella*, which, thereby, depart further from the known course of development in the Ascidiæ, and resemble rather the fresh-water Hydræ, if M. Laurent be correct in representing the young of the *H. grisea* as emerging, under the mature polype-form, from the ovum.*

The Anthozoa appear, without exception, to pass from the state of the ovum to that of the ciliated locomotive "gemmule" as the larva has been termed: most of them quit the parent in that guise: but in the large *Actiniæ* they appear occasionally to undergo their transformation into the polype-form before they escape from the mouth of the parent.*

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* CXXXI. pl. ii. figs. 11, 12, 13.

In the marine *Hydrozoa* the offspring developed in the ovicapsules are, as a general rule, the ciliated larvæ called "planulæ:" the *Plumularia coronata* offering an exception analogous to the *Alcyonella* in the highest, and the *Hydra* in the lowest, class of polypes; whilst other *Plumulariæ*, the *Corynidæ*, and certain species of *Campanularia* deviate in a still more remarkable manner by the development and liberation of the locomotive offspring in the guise of a minute *Medusa*.

We should be thus led from the Hydrozoa to the Acalephæ if we were guided solely by the phenomena of development; but more comprehensive views of the relations of the polype-shaped zoophytes have conducted to higher types than that from which the Acalephæ seem to diverge, and, in the necessarily consecutive course of description, we now find ourselves, as at the conclusion of the discourses on the Entozoa and Infusoria, compelled to retrace our steps and start afresh from a lower level of the broad basis of the animal pyramid.

Summary of the Classes, Orders, and Families of the Polypi of Cuvier.

Class HYDROZOA.

Tentacles hollow, muricated with dart-cells or thread-cells. *Stomach* without intestine, fixed in the parenchyme of the polype. *Polypary*, when present, flexible, external.

A. Naked, free, and solitary. Genus *Hydra*.

B. Naked, or sheathed in a thin membrane, fixed and compound: tentacles claviform. Family CORYNIDÆ. Genera, *Coryne*, *Syncoryne*, *Hydractinia*, *Corymorpha*, *Eleuthera*. (These, like the *Hydra tuba* of Dalyell, may be regarded as the procreating larvæ of Acalephæ.)

C. Protected by horny tubes, from the ends of which the polypes emerge. Family TUBULARIIDÆ. Genera, *Tubularia*, *Eudendrium*, *Pennaria*.

D. Protected by cells, developed according to regular patterns, from a rooted and ramified horny tubular polypary. Spermatozoa and locomotive progeny developed in external vesicles (sperm capsules or ovicapsules), larger than the polype-cells. Family SERTULARIIDÆ. Genera, *Sertularia*, *Plumularia*, *Campanularia*, &c.

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* CIX. vol. ii. p. 209.

Class ANTHOZOA.

Tentacles hollow, with thread-cells, and, in most, with pectinated margins. *Stomach* suspended by radiating mesogastric folds in an abdominal cavity: no intestine. *Polypary*, when present, usually internal.

A. Free and solitary, without polypary. *a.* Tentacles simple, rarely branched or clavate, more than twelve, often in more than one row. Family *Actiniidæ*. Genera, *Actinia, Actinodendron, Eumenides, Edvardsia*. *b.* Tentacles clavate and aggregated in tufts on the corners of the angular disc. Genus, *Lucernaria*.

B. Fixed, compound, without polypary. *a.* With many simple tentacles. Family *Zoanthidæ*. Genera, *Zoanthus, Mammilifera*. *b.* With eight pinnate tentacles. Family *Xeniidæ*. Genera, *Xenia, Anthelia*.

C. Fixed, compound, polypes with eight pinnate tentacles, retractile in cells of an amorphous fleshy substance, strengthened by detached calcareous spiculæ. Genera, *Alcyonium, Lobularia, Alcyonidium, Ammothea, Nephthya, Sympodium*.

D. Free, compound, polypes with eight pinnate tentacles, retractile in cells of a fleshy substance, strengthened by calcareous spiculæ, supported by, and sometimes arranged more or less symmetrically on a stem with a horny or calcareous axis. Family *Pennatulidæ*. Genera, *Pennatula, Virgularia, Renilla, Veretillum, Pavonaria*.

E. Fixed, compound, polypes with eight pinnate tentacles, retractile in calcareous tubes. Family *Tubiporidæ*. Genera, *Tubipora, Catenipora*.

F. Fixed, compound, polypes retractile in calcareous cells on the surface of a calcareous axis, which they cover with their common connecting tissue. *a.* With numerous and simple tentacles. Genera, *Fungia, Agaricia, Meandrina, Pavonia, Explanaria*. *b.* With more than twelve tentacles. Genera, *Turbinolia, Lobophyllia, Caryophyllia*. *c.* With not more than twelve pinnate tentacles. Genera, *Madrepora, Oculina, Astræa*. *d.* With the tentacles obsolete. Genera, *Millepora*.

G. Fixed, compound polypes, with eight pinnate tentacles, retractile in cells of a fleshy substance, strengthened by calcareous spiculæ, and supported on a branched, calcareous, firm or flexible axis. Genera, *Gorgonia, Corallium, Isis, Melitæa*.

Class BRYOZOA.

Tentacles hollow, with ciliated margins. *Alimentary canal* with stomach, intestine, and anus. *Polypary*, when present, external, horny or calcareous.

Family *Vesiculariidæ*; genera, *Vesicularia*, *Serialaria*, *Valkeria*, *Bowerbankia*. Family *Crisiidæ*; genera, *Crisia*, *Notamia*, *Anguinaria*. Family *Tubuliporidæ*; genera, *Tubulipora*, *Discopora*. Family *Celliporidæ*; genera, *Cellepora*, *Lepralia*, *Membranipora*. Family *Escharidæ*; genera, *Flustra*, *Tendra*, *Cellularia*, *Retepora*, *Eschara*. Family *Alcyonididæ*; genera, *Alcyonidium*, *Halodactylus*. Family *Alcyonellidæ*; genera, *Alcyonella*, *Cristatella*, *Plumatella*.

LECTURE IX.

ACALEPHÆ.

In the preceding lecture we saw that, whilst the new individuals propagated by gemmation were, for the most part, like the parent, those that came from the ova were in very few instances like the parent, but underwent a considerable metamorphosis. They quitted the egg-state either as a ciliated planula under the guise of a leucophrys, or were partially ciliated on special lobes, like a rotifer; or, what was more extraordinary, they came forth under the form of an animal which is usually ranked as a member of a higher class of Radiata, viz., a free-swimming, bell-shaped, or discoid medusa. The larger marine animals, so called, are commonly regarded as the typical forms of the class *Acalephæ*.

This class, the anatomy of which we have now to consider, comprehends creatures which are amongst the most singular of the whole animal kingdom; and each additional contribution to our knowledge of their economy adds to the interest, and indeed astonishment, with which the physiologist reflects upon it.

The *Acalephæ* are remarkable on account of the peculiar nature of their tissues, which are often as transparent as the purest crystal, and seem more like the vitreous humour than any other in the higher classes: they are not less interesting for the elegance of their forms, the beauty of their colours, and for the peculiar property which many of them possess of stinging and inflaming the hand that touches them, whence the name of "Acalephæ" applied to them by the ancient Greek naturalists, and "sea-nettles" by our own fishermen and sailors. These qualities, being presented by animals which are almost the sole visible representatives of living nature in the wild wastes of waters most remote from land, have always attacted the attention of the navigator, who sometimes finds the surface of the sea studded with these gelatinous gems, glistening by day with all the brilliant hues of the rainbow, and betraying their course during the night-season by the lambent phosphorescent light which they diffuse.* The *Acalephæ* are represented on our own coast by numerous discoid and spheroid species, varying in size from an almost invisible speck to a yard in diameter, and which, besides the vernacular name above cited, are known as "sea-blubber," "jelly-fish," or by the Linnæan generic term "medusa."

The form of many of the species is most typical of the great group "Radiata" as characterised in the "Règne Animal," and they were called by Lamarck †, on account of their tissue, "Radiaires Mollasses," or soft Radiaries, in contradistinction to the hard-skinned "Radiaires Echinodermes." Cuvier retained for them their ancient name of *Acalephæ*, and he characterises the class as free-swimming gelatinous animals, having a vascular system superadded to the digestive one, although he admits that the former may be only a continuation of the intestinal tubes ramified through the parenchyma of the body. ‡ He acknowledges, also, that the vascular system has not been demonstrated in every species of the class; and that those species in which it cannot be shown to exist, can hardly be distinguished from the Polypi.

The division of this class has been founded on their mode of locomotion. There are some singular forms which float by means of air-bladders, and in which the place of a stomach is supplied by many hollow tentacles: the Acalephes of this order are called "Physogrades," and have sometimes been denominated *Siphonophora*. In a second group locomotion is effected by longitudinal series of cilia, whence the name "Ciliogrades;" these have a single central mouth and a digestive cavity; they have also been called *Ctenophora*. The third order have also a central, but sometimes ramified, nutritive sac; and they swim by means of the rhythmical contractions of a musculo-membranous disc, whence they have been called "Pulmogrades" and "*Discophora*." The species of the last order are those that are most constantly met with in the seas washing our own coasts. But some of the tropical forms of the other orders are occasionally stranded on the south-western shores of England. I have picked up on those of Cornwall the little *Velella*, which had been wafted thither, unable to strike its characteristic latteen-sail; and there also I have seen wrecked a fleet of the "Portuguese men-of-war" (*Physalia*), which had been buoyed up by their air-bladders to that iron-bound coast.

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* The *Mammaria scintillans* has, perhaps, the greatest share in producing the luminosity of the ocean.

† CXXXVI. tom. ii. p. 450.

‡ XII. tom. iii. p. 274.

Extremely diversified are both the forms and powers of the free-swimming radiated animals which have been grouped together by the character of their gelatinous tissue and their independent movements. And, in testing the title of this group to be regarded a natural one, the zoologist has first to remark, that the animals so associated are characterised as they manifest themselves at one stage only of their existence; and has next to consider the question, what is the relation of this stage to the true or typical form of the species?

Zoological ideas of the typical form of a species appear to have been governed by different rules: as, e.g., according to the length of time during which a species may exist under a given form; or, according to the form most commonly presented to observation, and with which we are accordingly best acquainted; or, according to the superior number of the individuals of a species which present a given form, especially where such individuals are produced by gemmation, or otherwise parthenogenetically; or, lastly, according to the form finally assumed by the individuals developing the ova or spermatozoa. The three former circumstances have plainly influenced the best modern naturalists in the classification of such genera as *Campanularia* and *Coryne*, which have been placed amongst the Hydrozoa, with the distinctive character of "Progeny medusiform."

What may be the fate of this progeny, which swarm at certain periods, is not yet quite determined. M. Van Beneden's notion of their metamorphosis into the base of a compound parent, although seemingly natural, is hypothetical. Sars and Steenstrup's observations of what they believed to be generative organs* or ovaria, developed in the medusiform offspring of *Coryne*, more probably point to the right direction of the function and signification of such offspring. The fact that such medusiform progeny do engender ova seems to repose on good evidence, and is important, so far as it goes, and the processes by which the genetic cycle is completed will be indicated with much probability by the phenomena of that cycle which may be determined in the larger medusiform radiaries.

If these generate ova and spermatozoa, what then, it may be next asked, do their impregnated ova produce? If planulæ and polypes, then there will be strong ground for concluding the same with respect to the ova of the medusiform progeny of *Campanularia* and *Coryne*. That these compound, rooted, hydriform polypes do produce free-moving medusiform individuals, is most clearly determined; and the phenomena are most important and suggestive. No one who witnesses these changes in the form of different individuals, representing one and the same species, but must feel that, by prosecuting these researches, we shall arrive nearer and nearer to the possibility of solving those questions, the difficulty of which has been eluded by the gratuitous hypothesis of the transmutation of species, and which may lie at the bottom of the mystery of the progressive introduction of new specific forms of animal life upon this planet.

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* XCIII. p. 29.

"The natural system of classification," says Cuvier, "must be based upon a consideration of the totality of the organisation, and a comparison of such in different beings, directed by the principle of the subordination of characters." Granted. But suppose that organisation to materially change at different periods of the life of the individual of one and the same species, and these periodical characteristics to be propagable by parthenogenesis; which of these periods, it may be asked, is to be deemed to manifest the typical form, or that in which the whole organisation is to be studied and compared?

The philosophic botanist sees in the tree the same condition of an aggregate of essentially distinct individuals as the philosophic zoologist sees in the compound polype or the compound monad. No anatomist could look upon the polype of the Bryozoon, with its rich organisation and independent generative system, as a mere part or organ of a compound individual whole. No microscopical anatomist now regards the Volvox as any other than a spherical group of distinct and essentially independent monads. The polypes of the Anthozoa and of the Hydrozoa manifest the two lower grades of organisation in their sub-province; but are as essentially distinct individuals, as the polype of the Lagenella. The gemmiparous leaf of the Bryophyllum is the vegetable equivalent of the animal polype, and is equally a distinct individual plant; and, according to the present botanical philosophy, it is a more typical individual than the leaf which has been metamorphosed into the stamen, the pistil, or any other element of the flower.

By this analogy and course of reasoning, therefore, the naturalist would seem to adhere closest to Nature, and to interpret her best who should classify his subjects according to the typical character presented by the individual, whatever might be the phase of its development in reference to the genetic cycle; and the zoophytologists are justified on this principle who include the *Campanularia* and the *Coryne* amongst the Hydrozoa, notwithstanding their medusiform progeny. But, to be consistent, the rule should be extended to other medusiform progeny of hydriform polypes, and so to many of the larger acalephæ.

Such a modification, amounting virtually to a suppression, of the class *Acalephæ*, however consistent with the reasoning based upon the principles which have been just laid down, would be opposed to the practice of naturalists in almost every instance, except the *Campanularia* and *Coryne*, and a few analogous cases of compound polypes with medusiform oviparous individuals.

The cockchaffer lives laboriously three dark years under ground, eroding the roots of plants, before it emerges into light, and disports a few merry weeks in the bright summer sunshine, in its winged state. The vermiform larva, in giving birth to the winged insect, has exhausted most of its substance, and all its vital energies as such, and leaves nothing but its empty skin behind.

The ephemeron, after a year's obscure existence as a water-worm, creeps out of the vermiform case, and uses its newly-acquired aerial locomotive organs, and its procreative powers, for a brief day or hour.

We do not, however, class the cockchaffer and the may-fly with the Vermes, as we ought to do according to the analogy of the *Campanularia* and *Coryne*. So vast a proportion of the parent worm has supplied the material to the plastic force, which has operated in the re-arrangement of parts for the completion of the winged insect, that we say the worm has been *converted* into the insect.

The larval aphides, however, unequivocally propagate, and so frequently, as quite to parallel the condition of the procreant larvæ of the medusa-producing polypes; and the analogy is both true and close of the winged male and oviparous female aphides to the locomotive male and female medusæ and to the male and female modified leaf-individuals of plants. Yet, notwithstanding these analogies, another rule guides the zoologist in the majority of such cases, which is this: to regard as the typical phase of the species that most perfect form which parallels the winged state of the insect, the medusa state of the polype, and the seed-producing and pollen-bearing flower-parts of the plant. And the zoologist accordingly classes the batrachian and the butterfly, the chaffer and the ephemeron, the beröe and the medusa, according to the structure of the last phase of their development.

Few naturalists will be found to object to this: but, to be consistent, they ought not to place in separate classes the *Campanularia* and the *Cyanæa*.

The bell-shaped medusoid which Dalyell saw struggling to escape from the ovicapsule of the *Campanularia* is the equivalent, or homologue, of the ciliated planula which, in like manner, escapes from the ovicapsule of the *Sertularia;* and the difficulty or inconsistency cannot be eluded by affirming the bell-shaped meduseid to be a "locomotive ovarium," a mere organ of the compound polype that produced it.

In the pulmograde Acalephæ the body is chiefly composed of the "disc," which is circular, almost flat in some, e.g. *Æquorea*, but rising in others by degrees to a hemispheric form, and becoming nearly cylindrical, as, e.g. in *Turris*. It is usually smooth, rarely pilose. Around its margin there is, in many species, a projecting ledge of membrane called the "velum," and the margin itself is usually provided with more or less numerous tentacles, and with the "cysticles" and pigment specks. From the centre of the under surface of the disc there depends a simple or complex, long or short, process, called the "proboscis," including more or less of the digestive cavity.

The most characteristic features recognisable by the naked eye, in the organisation of the Acalephæ, may be exemplified by the anatomy of the larger Medusæ of our own seas.

The first thing which astonishes us in commencing the dissection of these creatures is the apparent homogeneity of their frail gelatinous tissue; secondly, the very large proportion of the body which seems to consist of sea water; for let this fluid part of a large Medusa, which may weigh two pounds when recently removed from the sea, drain from the solid parts of the body, and these, when dried, will be represented by a thin film of membrane, not exceeding thirty grains in weight. The anatomist is baffled by the very simplicity, as it seems, of his subject, instead of, as in other cases, by the inability to pursue and unravel all the obvious intricate combinations of the created mechanism. Péron and Lesueur, two experienced French naturalists, who, during the circumnavigatory voyage to which they were attached, paid great attention to the floating Acalephæ, have thus summed up the results of their experience in regard to their organisation. "The substance of a Medusa is wholly resolved, by a kind of instantaneous fusion, into a fluid analogous to sea water; and yet the most important functions of life are effected in bodies that seem to be nothing more than, as it were, coagulated water. The multiplication of these animals is prodigious; and we know nothing certain respecting their mode of generation. They may acquire dimensions of many feet diameter, and weigh occasionally from fifty to sixty pounds; and their system of nutrition escapes us. They execute the most rapid and continued motions; and the details of their muscular system are unknown. Their secretions seem to be extremely abundant; but we perceive nothing satisfactory as to their origin. They have a kind of very active respiration; its real seat is a mystery. They seem extremely feeble, but fishes of large size are daily their prey. One would imagine their stomachs incapable of any kind of action on these latter animals: in a few moments they are digested. Many of them contain internally considerable quantities of air; but whether they imbibe it from the atmosphere, extract it from the ocean, or secrete it from within their bodies, we are equally ignorant. A great number of these Medusæ are phosphorescent, and glare amidst the gloom of night like globes of fire; yet the nature, the principle, and the agents of this wonderful property remain to be discovered. Some sting and inflame the hand that touches them; but the cause of this power is equally unknown." *

In this series of lively paradoxes the more obvious characters of the Acalephæ are strikingly exemplified; but I have quoted them rather to contrast with the actual knowledge which has since been gained on these points, and as showing how little the best and most abundant opportunities of observing the Acalephœ will avail, if the higher powers of the microscope be not brought in aid of the investigation. Before, however, entering upon these results of later researches, let us see what Hunter was able, by the ordinary anatomical procedures, to demonstrate and leave for our instruction. In these specimens†, which belong to the genus *Rhizostoma*, he has inserted his skilful injecting apparatus into the central cavity of the body (*fig.* 75, *a*), plunged, so to speak, "in medias res," and made conspicuous by his coloured injection, both the extraordinary route by which the nutriment reaches that cavity, and also the channels by which it is distributed for the support of the general system. The prolongation of the common cavity *a* into the base of the proboscis (*b*) there divides into four canals (*c*), which enter the base of the four branches (*p*, *p*), into which the proboscis divides. These branches again divide and subdivide along their plicated borders; the nutrient canals follow these ramifications, and terminate in numerous fringed pores (*d*, *d*),

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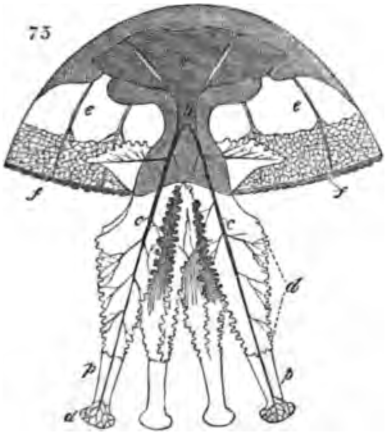

Rhizostoma.

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* CXXXVII. p. 219.

† Nos. 847. 982, 983.

upon the ultimate ramifications at the margins and clavate ends of the proboscis. These pores are, in truth, the commencement of the nutritive system; they are, in this respect, analogous to the numerous polype-mouths of the compound coral zoophyte*; but in the Rhizostome a common central sac is interposed between the ingestive conduits and the vascular or chylaqueous system of the body. Minute animalcules, or the juices of a decomposing and dissolving larger animal, are absorbed by these pores, and are conveyed, more or less digested "in transitu," by the successively uniting canals to the central cavity. Digestion being completed, the chyle passes at once into the vascular system, which is in fact a continuation and ramification of the digestive cavity. The nutrient fluid, with sea-water, passes by vessels (*e*), which radiate from that cavity, to a beautiful net-work (*f, f*) of large capillaries, which is spread upon the under surface of the margin of the disc. The elegance and precision with which the injections of Hunter have demonstrated this network in his preparations cannot be surpassed; but it is to Cuvier that we owe the first description of the very remarkable and interesting system of nutrition in the Rhizostome.†

The rich development and reticular disposition of this part of the vascular system, in which the circulating fluids are exposed to the surrounding medium in a state of minute subdivision, upon that surface of the body which rests upon the water, indicate that the respiratory interchange of the gases, and the absorption of the oxygen from the air contained in the sea water, take place principally at this vascular surface of the gelatinous disc; and that Hunter is correct in placing it amongst the series of respiratory organs. It stands, indeed, at the lowest step of that series, since the organ is not specially eliminated; but only indicated or sketched out, as it were, by a modification of part of the common integuments.

The *Cyanæa aurita*, another species of our coasts, exemplifies another (monostome) type of the digestive system. The homologue of the central cavity in *Rhizostoma*, and which in *Cyanæa* must be the digestive sac, consists of four cavities, from which as many short œsophageal tubes are continued to their commencement, upon the under surface of the body, by a single quadrangular mouth (*fig.* 76, *a*) with the angles prolonged into four tentacles which consist of a solid hyaline axis, with two fimbriated membranes along their under surface. Sixteen canals radiate from the central cavities, eight of which (*b*, *b*) form, by their ramifications, the systems of nutrient and respiratory capillaries and terminate in a circular canal near the margin of the disc; whilst the alternate eight terminate without dividing, each by a minute excretory orifice (*c*) at the margin of the disc.

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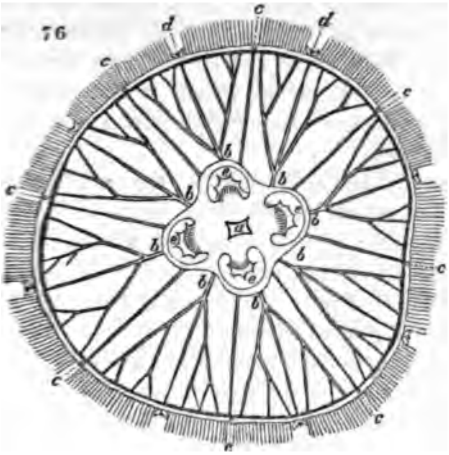
* LXXXIV. (1843.) p. 104. Mr. Huxley, who describes the oral pores in *Rhizostoma* as opening obliquely in a channel formed by two irritable marginal membranes, states that in *Cephæa* the membranes unite in front of and behind each pore "so as to form a distinct polype-like cell." The outer membrane and the richly-ciliated lining membrane of the digestive canals unite at the free edge of the fold, and are there produced into tentacles. Believing the business of digestion to be performed in the minute dilatations of the beginning of the canals collected upon the edges and extremities of the ramuscules of the proboscis, he carries out the analogy suggested in the text, and observes "that the Rhizostomidæ, *quoad* their digestive system, have the same relation to the monostome Medusæ, as the Sertularian Polypes have to the Hydræ, or the coralline Polypes to the Actiniæ." Phil. Trans. 1849., p. 414.

† CXXXVIII. p. 436.



Cyanæa.

We must suppose the mouths of these excretory vessels to be endowed with an irritability of a different kind from that of the nutrient canals, like the mouths of the different cavities of a ruminating stomach. For, as the orifices of the third and fourth stomachs contract upon the coarse unmasticated food, whilst those of the first and second open to receive it, and close when it is presented to them in its remasticated state, so the nutrient diverticula of the stomach of the Cyanæa receive the digested and exclude the excrementitious part of the food, which passes along the efferent canals and is thus rejected from the system.

The discovery of this condition of the nutrient apparatus in the *Cyanæa aurita* is due to the ingenuity and perseverance of Prof. Ehrenberg, who induced the living animals to swallow indigo with their food. He has represented the canals so injected, in the elaborate plates of his memoir on the anatomy of this species.* Prof. Wagner† saw the currents of the nutrient fluid in the vascular system of the Oceania: they were produced, not by peristaltic contraction of the canals, but by the vibration of the cilia lining them.

In the "bare-eyed" Medusæ digestion is chiefly if not exclusively performed in the cavity of the proboscis. At the fundus of this cavity Will saw in *Geryonia pellucida* four small obtuse prominences, each of which presented a small aperture leading to the system of the ciliated chylaqueous canals. In *Thaumantias leucostylus* he found a distinct ciliated cavity separated from the stomach at its base and from which the chylaqueous vessels sprang. Prof. E. Forbes also found either a well-defined cavity at the base of the stomach or an indication of such a cavity, from which the chylaqueous vessels were continued.* This cavity and system of vessels is homologous with that to which I have given the name "chylaqueous" in the Anthozoic and Sertularian polypes.

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* CXL. p. 189. taf. i. and iv. fig. 2., *z.*

† CXLII.

A progressive simplification of the appendages of the mouth may be traced from the Cyanæa downwards in the small bare-eyed, and probably larval forms of Medusæ: in *Geryonia* and *Oceania* the lips are produced into fimbriated lobes; in *Circe* and many species of *Thaumantias* into simple lobes; in *Sarsia* the lip is a thickened ring round the orifice of the tubular digestive cavity.†

In all Pulmogrades the inner or lining membrane of the digestive and nutritive cavities and canals is soft and cellular, and lined by a ciliated epithelium: it is applied either to the gelatinous basis of the disc, or directly to the integument, or to the walls of the generative cavities (*e e, fig.* 76.). The gelatinous basis of the disc in *Rhizostoma* consists of "an apparently homogeneous substance containing a multitude of delicate fibres interlacing in every direction, in the meshes of which lie scattered nucleiform bodies:" ‡ its upper surface is covered by a tessellated epithelium of polygonal nucleated cells; on the lower surface the epithelium "is replaced by a layer of parallel muscular fibres."§ The integument contains many cells analogous to the thread-cells in the Hydrozoa and Anthozoa, and to which Prof. Wagner has ascribed the function of urticating, calling them "nettle-cells" (nessel-organe). ‖ These cells are usually of an oval form and contain a long filament, which when retracted is spirally disposed, but darts out, often to considerable length, when the skin is touched. They are very numerous in the strongly urticating *Pelagia noctiluca:* in the feebly urticating *Oceania* they are principally located in the marginal tentacles; and Ehrenberg, who detected them in the stinging tentacles of the *Cyanæa capillata* ¶, could not find them in the disc of that species. Will[*] could discover them only in the generative tentacles of the *Cephea*, and in the marginal tentacles of the *Polyxenia*. When in action the capsule of the thread-cell is first protruded from the skin and the filament afterwards.

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* CXLVII. p. 4. † CXLVII. p. 8 ‡ CXLV. p. 415.

§ CXLV. p. 416. ‖ CXLIII. p. 38.

¶ Prof. E. Forbes states that only a small minority of the medusæ of our seas are stingers, and amongst these the *Cyanæa capillata* is a formidable one, and "the terror of tender-skinned bathers. With his broad tawny, festooned, and scalloped disc, often a full foot or more across, it flaps its way through the yielding waters

Some superaddition to the thread-cell would seem, however, to be essential to the urticating faculty, since those cells are present in species and parts that do not sting.

Another kind of cell, analogous to the "dart-cells" of the Hydra, is also present in the Acalephæ, and consists of an oval capsule from which a stiff bristle-like spine protrudes: these do not urticate: they lie in groups in the skin of the disc of the non-urticating species, and are very abundant in the marginal, oral, and generative tentacles of such species.

The oral tentacles, those, viz. which are continued from the fringed margins of the oral pores in *Rhizostoma* and *Cephea*, are productions of the outer membrane or integument, and are solid, as are also the marginal tentacles in the same genera. The short tentacles produced from the membrane depending from the mouth in *Mesonema* contain "a central axis made up of large transparent cells, and extending beyond the base of the tentacle into the substance of the membrane." The marginal tentacles in *Mesonema*, *Oceania*, and *Cyanæa* (*fig.* 76.) are hollow, and lined by a continuation of the ciliated epithelium of the marginal canal. The large interbrachial tentacles of *Cephea* are processes of the branched proboscides and have the same structure, consisting of a thick transparent outer substance and an inner membrane inclosing a tubular canal: but at the extremity they are thickened, and the outer wall is raised into a number of small pyriform processes. The central canal branches into a kind of plexus which occupies the interior of the enlarged end of the tentacle. In the smaller tentacles which depend from the concavity of the proboscidian base the central canal terminates in a simple blind end.[†]

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and drags after it a long train of riband-like arms, and seemingly interminable tails, marking its course when the body is far away from us. Once tangled in its trailing "hair," the unfortunate, who has recklessly ventured across the graceful monster's path, too soon writhes in prickly torture. Every struggle but binds the poisonous threads more firmly round his body, and then there is no escape: for, when the winder of the fatal net finds his course impeded by the terrified Human wrestling in its coils, he, seeking no combat with the mightier biped, casts loose his envenomed arms, and swims away. The amputated weapons, severed from their parent body, vent vengeance on the cause of their destruction, and sting as fiercely as if their original proprietor itself gave the word of attack." CXLVII. p. 10.

[*] CXIV. p. 62.

[†] CXLV. pp. 418—420.

The tentacula in the British species of bare-eyed Medusæ are simple, usually filiform, and highly contractile. "Each of these organs," writes Prof. E. Forbes, "may be extended or contracted singly, or in concert with its fellows, evidently obeying promptly the will of the animal of which they form part. They guide the Medusa through the sea, and can anchor it. I have seen a *Geryonia* anchor itself by means of its lips, clasping a coralline with them, and remaining tranquil so fixed for a considerable time." *

The Medusæ swim by the contractions of the margin of their disc; and Hunter has put up a corrugated portion of the under surface of this part of a Rhizostoma † which he considered as indicative of the arrangement of muscular fibres in that part. Subsequent microscopic observations have confirmed the accuracy of his views of this structure.

The fibres run parallel with each other, with occasional interruptions in their course ‡, and their component fibrillæ, like those in *Oceania* and *Pelagia noctiluca* §, present the transverse striated character of voluntary muscle. Prof. E. Forbes states that he has paralysed one side of a *Rhizostoma*, whose disc measured more than a foot across, by removing with a scalpel the subdiscal fibrous bands of that half, whilst the other side contracted and expanded as usual, though with more rapidity, as if the animal was alarmed or suffering. ‖

The evidence of distinct nerves and ganglions in the pulmograde Acalephæ rests, at present, on the interpretation which Ehrenberg has given of certain appearances in connection with the eight brown marginal "cysticles" (*d, d, fig.* 76.), which in the *Cyanæa aurita* are made conspicuous by a speck of red pigment on their upper or dorsal side. He describes a glandular, bi-crural ganglion at the base of each of these cysticles, interprets the cysticles as "eyes," and the two crura of the ganglion as optic nerves. Ehrenberg also describes a smaller ganglion, shaped like the above, between each pair of the marginal tentacles. ¶ Mr. Huxley is disposed, from the analogy of what he has observed in *Rhizostoma* and *Phacellophora*, to regard the so-called "optic nerves" as merely the thickness of two superimposed membranes, "and a very similar explanation may be given of the intertentacular ganglia, which appear to be nothing more than the optical expression of the thickened walls of the circular canal." **

With regard to the part, which, from its characteristic constancy under a certain range of modifications in the Acalephæ, I have proposed the definite term of "cysticle"[*], I may remark that Gaede first described, in *Medusa aurita*, eight of these bodies in the margin of the disc, which to the naked eye appear as white points, but under the microscope are seen to be hollow bodies containing at their free end minute corpuscles[†], the uppermost of which are grayish, the undermost brownish, and all of them more or less hexangular. Ehrenberg compares these corpuscles with the crystals of quartz, but found them, contrary to Rosenthal's statement, soluble and effervescent in sulphuric acid. Observing a little cell filled with red pigment granules above each cysticle in the *Cyanæa auricula*, the same eminent micrographer suggested that they might be organs of vision analogous to the ocelli or coloured specks in *Rotifera* and *Entomostraca*.[‡]

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* CXLVII. p. 4. † Prep. No. 55. ‡ CXLV. p. 424. § CXLII
‖ CXLVII. p. 3. ¶ CXLI. p. 572. ** CXLV. p. 418.

In all the larger Medusæ which are characterised by a much ramified and anastomosing series of chylaqueous vessels the cysticles are protected by more or less complicated membranous hoods or lobed coverings: in the smaller Medusæ which possess a more simple chylaqueous system, the radiating canals of which are either unbranched, or if ramified, not anastomosing, the cysticles are unprotected, exposed, and often obsolete. Prof. E. Forbes, adopting Ehrenberg's idea of their function, proposes to divide the Pulmogrades into the Steganopthalmata and Gymnopthalmata. In the latter or bare-eyed family the pigment-cells associated with the cysticles vary much in colour, being purple, orange, yellow, black and even variegated, in different species. Yellow with a red dot is a common condition and is well defined in Oceania.*

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[*] *Hohlen Körper mit Körperchen*, Gaede. *Rand Körpern und Auge*, Ehrenberg. *Tubercules vesiculaires*, Edwards. *Gehörblaschen*, Will. *Gehörwerkzeuge*, Siebold. In the excellent monograph, CXLV., they are called, in paragraph 21, "marginal corpuscles," in the next paragraph "marginal vesicles;" in par. 22 "the corpuscle" simply. In the description of the plates, "fig. 8. is a portion of the marginal canal, with a tentacle, and two *marginal corpuscles*. Fig. 9. portion of the marginal canal, with a young tentacle, and a *marginal vesicle*, containing *two corpuscles*." (p. 431), the same name being sometimes applied to the contents, and sometimes to the thing containing, or to the whole organ. One so zealous for the right understanding of the structures of the marine invertebrata, as the clear-sighted author of CXLV., will be the first to excuse the attempt to remove a source of ambiguity in any detail of their descriptive anatomy. I have proposed for the constant and remarkable organ in question, the term "cysticle" (from *cysticula*), instead of cysticule, agreeably with the analogy of "tentacle," and "peduncle," applied to other parts of the Acalephæ. This single-worded name has also the advantage of suggesting no hypothetical view of function.

[†] "Unter dem mikroskop aber wird mann einen hohlen Körper gewahr, der an dem einen freien Ende viele kleine Körperchen trägt." CXXXIX. p. 18.

[‡] CXLI. p. 574, 575.

In some Acalephæ the cysticles are not complicated with pigment-cells. In the *Æquorea violacea* the marginal tentacular interspaces are divided by a mammillary process, on each side of which are two cysticles, of an oval or spherical form, containing each two or three spherical corpuscles.† In *Geryonia*, *Thaumantias*, *Oceania* and *Polyxenia* the cysticles are sessile upon the circular vessel, and placed between its inner and outer membranes: in *Phacellophora* as in *Cyanæa*, each cysticle is placed at the extremity of a short double-walled tubular pedicle projecting downwards, the under margin of the fissure in which it is lodged being prolonged into two overlapping fringes, whilst the pedicle is a prolongation of the marginal system of canals. In *Cephea* and *Rhizostoma* the cysticle is placed in a notch between two lobe-like processes of the margin of the disc and looks upwards. On the upper surface a semilunar fold extends from one lobe to the other and covers the cysticle.‡ The cysticles are below the marginal tentacles in *Thaumantias*, but alternate with them in the nearly allied *Geryonia*.§ The cysticles are yellow in *Pelagia noctiluca*, but colourless in *Cassiopæa* and *Aurelia*, and the colourless pedunculate marginal cysticles of *Polyxenia leucostyla* contain each a single round corpuscle, whilst the cysticles of *Cytaeis polystyla* contain a cluster of yellowish calcareous corpuscles.‖ Will and Siebold regard these contained corpuscles as homologous with the otolites of higher animals and the cysticle as an organ of hearing¶; its cavity is lined by vibratile cilia in *Oceania***, which impress a vibratile movement upon the contents, like that which characterises the otolitic corpuscles in the Mollusca. As the pigment-cell, when present, is distinct from the cysticle it may do the office of a light-appreciating organ, and the cysticle that of a simple organ of hearing. We may with much reason regard as organs of touch the labial and marginal tentacles.

The ciliograde Acalephæ are beautifully represented in seas that wash our coasts by the little semi-transparent, delicately-tinted, spheroidal animals (*fig.* 77.) called *Beroë* by Müller, and now the types of many genera, which have this in common, that their chief organs of motion consist of unusually large vibratile cilia, aggregated in lamelliform groups (*ib. c, c*), which seeming plates are arranged

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* CXLVII. p. 9.

† CXLVI. p. 196. pl. 1. fig. 1c., *c, c.*

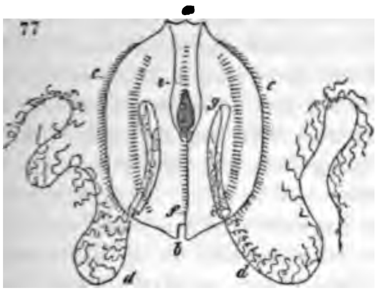
‡ CXLV. p. 416.

§ CXLVII. p. 8.

‖ CXIV. pp. 64. 68.

¶ XXIV. p. 61.

** Observed by Kölliker, quoted in CXLVII. p. 9.



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Cydippe.

like the paddles of a propelling wheel, along eight equidistant convex bands, extending from near one end or pole of the body to near the other, like the meridians of an artificial globe. The organs by which the Beroë can attach itself to, or poise its body on, a solid surface, are two very long tentacles, which are fringed on one side with cirri. These cirrated tentacles (*d*, *d*, *fig.* 77.), which can be stretched out in some species to more than twenty times the length of the body, can be instantaneously retracted into the two cavities or sheaths which extend along each side of the slender intestine; the marginal cirri in this act being as instantaneously coiled up in a series of close spirals, and the whole complex tentacles compacted within the limits of a pin's head.

"Like a planet round its sun, or, more exactly, like the comet with its magic tail, our little animal moves in its element as those larger bodies revolve in space; but, unlike them, and to our admiration, it moves freely in all directions, and nothing can be more attractive than to watch such a little living comet, as it darts with its tail in undetermined ways and revolves upon itself, unfolding and bending its appendages with equal ease and elegance; at times allowing them to float for their whole length, at times shortening them in quick contractions, and causing them to disappear suddenly, then dropping them, as it were, from its surface, so that they seem to fall entirely away, till, lengthened to the utmost, they again follow the direction of the body to which they are attached, and with which the connection that regulates their movements seems as mysterious as the changes are extraordinary and unexpected. For hours and hours I have sat before them and watched their movements, and have never been tired of admiring their graceful undulations. And although I have found contractile fibres in these thin threads, showing that these movements are of a muscular nature, it is still a unique fact in the organisation of animal bodies, that by means of muscular action parts may be elongated and contracted to such extraordinary and extensive limits. At one moment the threads, when contracted, seem nodose; next, the spiral, elongating, assumes the appearance of a straight or waving line. But it is especially in the successive appearances of the lateral fringes, arising from the main thread, that the most extraordinary diversity is displayed. Not only are they stretched under all possible angles from the main stem, at times seeming perpendicular to it, or bent more or less in the same direction, and again as if combed into one mass; but a moment afterwards every thread seems to be curled or waving, the main thread being straight or undulating, then the shorter threads will be stretched straight for some distance, and then suddenly bent at various angles upon themselves, and perhaps repeat such zigzags several times, or they will be stretched in one direction, then they will be coiled up from the tip, and remain hanging like pearls, suspended by a delicate thread to the main stem, or, like a broken whip, be bent in an acute angle upon themselves, with as stiff an appearance as if the whole were made up of wires; and, to complete the wonder, a part of the length of the main thread will assume one appearance, and another part another, and pass from one into the other in the quickest possible succession, so that I can truly say I have not known in the animal kingdom an organism exhibiting more sudden changes, and presenting more diversified and beautiful images, the action, meanwhile, being produced in such a way as hardly to be understood. For, when expanded, these threads resemble rather a delicate fabric spun with the finest spider's thread, at times brought close together, combed in one direction without entangling, next stretched apart, and preserving in this evolution the most perfect parallelism among themselves, and at no time, and under no circumstances, confusing the fringes of the two threads. They may cross each other, they may be apparently entangled throughout their length, but let the animal suddenly contract, and all these innumerable interwoven fringes unfold, contract, and disappear, reduced, as it were, to one little drop of most elastic India rubber." *

If we regard with Agassiz the halves of the body of the Beroë, which might be divided by a plane passing through the split of the oblong mouth, as "right" and "left," the tentacles are there placed one on the right, and the other on the left, side of the animal.

The transverse mouth, situated in *Cydippe* at the extremity marked *a*, *fig.* 77., is bounded in most ciliogrades by lobes, and the buccal membrane in some species is produced into minute and highly contractile tentacles. Below these the alimentary canal expands into a moderately wide stomach extending about half-way towards the opposite pole. The form of the cavity varies according to its state of contraction, from circular to oblong or angular. Towards the fundus the walls of the stomach present four folds, which are lined by brown cells, like those in the Hydra, and probably fulfilling an hepatic function. The ciliated epithelium is best developed at the bottom of the stomach. This part of the digestive sac communicates with a ciliated chylaqueous (nutritive and respiratory) cavity, comparable to that in Actinia (*fig.* 63. *g*, *g′*), by two small apertures, each guarded by a sphincter. The chylaqueous cavity surrounds the stomach, beyond which its narrower end extends vertically as a cloacal canal to the pole opposite the mouth, where it terminates by two small excretory outlets. Between and below the sheaths of the tentacles (*g*, *g*, *fig.* 78.) the chylaqueous cavity sends out transversely two wide canals in opposite directions, which bifurcate at acute angles, each branch again bifurcating at similar angles (somewhat as shown in the transverse section of the *Cydippe*, *fig.* 78., but varying according to the point of view), thus sending off eight radiating horizontal canals, which send off as many vertical canals along the whole extent of the eight rows of vibratile fringes ; branches are also sent to supply the tentacular sheaths, and two tubes extend vertically along the flat surface of the stomach to the margin of the mouth. At the oral end of the spheroid the longitudinal canals communicate with a circular one, and a similar circular vessel surrounds the anal disc, in *Beroë Forskalii.*[*]

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* This beautiful description is given by Agassiz, in his valuable and elaborate monograph, CXLVIII. pp. 314, 315.

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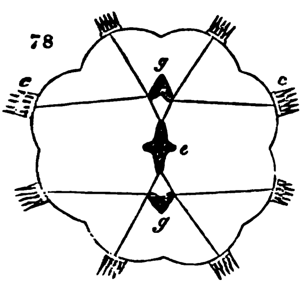

Cydippe.

Will[†] has given a good description and figure of the infundibular chylaqueous cavity, and the canals sent off to the stomach, to the long and short rows of cilia, to the tentacles and the body-lobes, in the *Eucharis multicornis*, a lobed Beroë, belonging to the same family as the *Lesueuria* of Edwards and the *Bolina* of Agassiz, who confirms, in the main, this account, in his elaborate description of the chylaqueous system of a North American Beroë (*Pleurobrachia rhododactyla*, Ag.[‡]). In this species M. Agassiz observed that, besides the movement of the chylaqueous fluid due to the ciliated epithelium lining the system containing it, the parietes of the central cavity of the main trunks, as well as those of the vessels to the ciliated bands, contracted and dilated ; and that the dilatation of the vessels of one side of the body alternated with the dilatation of those of the other side. Chyle, or reduced chymous particles of the food, with sea-water, circulates freely through the cavity and canals of the system above-described, and effete particles are sent out with the fluid by the excretory pores, which are homologous with those of the corresponding system of canals in the *Cyanæa* (*fig.* 76. *c*, *c*), and only remotely analogous to the anal outlet of the true intestinal canal in the ***Bryozoa*** and higher forms of animals. In *Cytaeis*, *Geryonia*, and *Thaumantias* four canals are continued from the digestive chylaqueous cavity to the marginal circular canal; whilst in *Æquorea* not fewer than seventy-four canals radiate from the stomach to the marginal canal.

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[*] See the beautiful figure of the system of ciliated chylaqueous canals, injected in CXLVI. pl. 6. fig. 1., *a*.

[†] CXIV. p. 31. tab. i. fig. iii.

[‡] CXLVIII. pp. 332—339. pl. iii. and iv.

Agassiz has described the longitudinal muscular fasciculi beneath the superficial rows of vibratile fringes, and the pinnate bundles of fibres attached to the sides of those rows, and which penetrate into the substance of the gelatinous mass. By means of these muscles, the fringes, although they usually move together, yet sometimes act independently, and even particular cilia in each lamelliform fringe may move whilst the others are at rest. The same acute and indefatigable observer has figured the radiating fibres of the muscles which dilate the mouth, and the circular fibres which close it, and the diverging fibres of the main vertical fasciculi, which form a kind of sphincter around the tube leading into the tentacular sheath.*

The evidence of the nervous system in the Ciliogrades is doubtful and conflicting.

Dr. Grant† has described and figured a double filamentous chord connecting a chain of eight ganglions around that extremity of the *Beroë* (*Cydippe*) *pileus* (*fig.* 77, *b*), from near which the two long cirrigerous tentacula (*d d*) are protruded, and where he supposed the mouth to be placed. Whatever analogy such nervous system may bear to that of the Echinoderms in the circular disposition of the central filaments, and the radiation of nerves from that centre, it has none in regard to its situation, for the mouth of the Beroë is at the opposite end of the body.‡

Milne Edwards § and Will ‖ both reject the above described nervous system. A single cysticle appears to be present in all Beroïdæ at the anal pole of the body, in a depression, protected by lobes of the integument; and beneath the cysticle is a yellowish mass of a ganglionic appearance, which both the above-cited observers refer to the nervous system. The cysticle contains some clear fluid with an aggregate of crystalline corpuscles of a white colour, in Cydippe and Eucharis, of a reddish tinge in Beroë. These corpuscles vibrate by the action of the cilia of the lining epithelium of the cysticle. Some superimposed dark-coloured pigment-cells render its situation conspicuous. By some anatomists the combined cysticle and pigment-cells have been regarded as a simple organ of vision, by others as a simple organ of hearing; both would probably be right if they would limit the one sense to the pigment spot, the other to the cysticle. The remarks by M. Agassiz on the nervous system of the Beroïdæ appear to me so just, and accord so well with the conclusions to which my own observations have led, that I cannot better conclude my notice of this part of the ciliograde structure than by quoting them: —

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* CXLVIII. pp.332—339. pl. 2. *n*, *o*, *p*.

† CXLIX. p. 10. pl. 2. f. 1.

‡ CXLVII. p. 206. pl. 4.

§ CXLVI. p. 207.

‖ CXIV. p. 44.

"As for the nerves which are said to arise from the ganglion connected with this black speck, I have been unable to make them out. I have seen numerous muscular or contractile fibres connected with the lower extremity of the chymiferous funnel; I have seen these fibres diverging from above the so-called ganglion, but have never been able to trace any one of them beyond the length which contractile fibres have; again, I have repeatedly seen these fibres in a state of contraction or relaxation, presenting so little regularity in their distribution, that for the present I think it were rather assuming to decide upon the disposition of the nervous system of Beroïd Medusæ. I am even satisfied, from the descriptions published, that the eight converging narrow tubes, of which I find no mention in former authors, must have been probably mistaken for nervous threads by some; and when Professor Grant states that Beroë has eight nervous threads, I suppose he alludes to the eight narrow chymiferous tubes, the connection of which with the ambulacral tubes is so easily traced, though their central connection with the vertical funnel still remains doubtful. I do not, however, deny that this centre" (the cysticle), "is a point where we have to look for at least one part of the nervous system, and the gelatinous lobes about the mouth for the other part, if there be really a distinct nervous system in Beroïd, as in Discoïd Medusæ. But, for my own part, I have failed in tracing it out; though, I may add, that I am sufficiently acquainted with the structure of the region where it is said to have been observed, to doubt the accuracy of the statements which have been made about it, especially in the precision and distinctness with which it is mentioned. And I express these doubts notwithstanding the doubts I have myself respecting the real nature of some organs around the central black speck, for the very reason that, after finding there more than has been seen and described, and various things which may answer the vague description given, I do not in reality find what has been said to exist in that part of the animal." *

The most conspicuous, if not the most typical, member of the physograde order of Acalephæ is the *Physalia* (*fig.* 79.), in which all that part answering to the disc in the "pulmograde" order, is expanded into a bag, the major part of which is occupied by an air-bladder, whilst the digestive cavity is subdivided amongst a series of appendages attached to one part of the under surface of the bag. This part consists of an outer thin and dense membrane, of an inner thicker membrane beset with long cilia, and of an air-bladder, which at one point, *a*, is attached to the above membranes, where there is a small constricted aperture, at least in the outer membrane. This membrane is developed into a kind of crest along its upper part. It is provided with many fine muscular fibres, and the whole bag contracts into a small irregular mass when punctured and the air evacuated; but it seems that the Physalia has no power of voluntarily emptying its air-bag.

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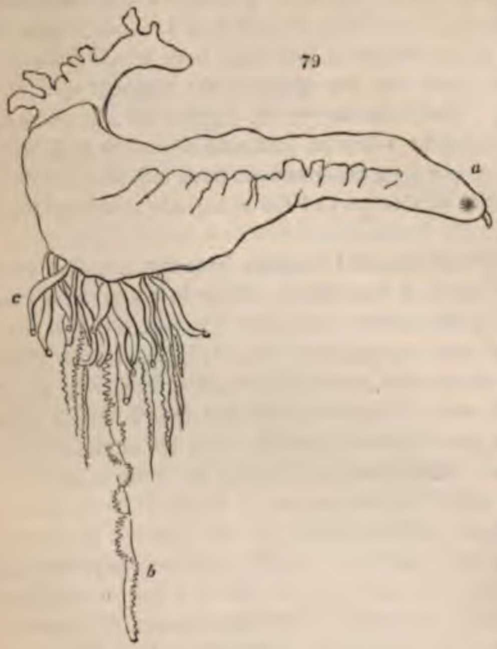

Physalia.

The appendages are of three kinds, — urticating, digestive, and (probably) generative. The urticating tentacles are the longest; they are hollow, and are provided with muscular fibres, of which the most conspicuous are longitudinal, and serve to retract them; they contain many corpuscles of a reniform shape, and are richly provided with thread-cells, whose filaments are of the spiral kind. The gastric appendages are shorter and wider, and are provided with stomata, which are applied to the prey seized and benumbed by the tentacles If the prey be small, it is sucked bodily into the gastric sac; if large the sac becomes distended with its juices and dissolved parts, the gastric secretion being a very rapid and powerful solvent. The mouth of each sac is wide, with a broad everted lip, armed with a series of "nettle-cells." The whole gastric appendage is highly contractile and in constant motion in the living animal. The appendages of the third class are cyathiform; the development of generative parts has not yet been followed out in these. The question of the genetic cycle of the Physalia is one of the most interesting that remains open to the observations of the naturalist who may traverse the tropical seas where they most abound.

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* CXLVIII. p. 348.

The *Physophora* differs from the Physalia in having, besides the principal or axial air-bladder, a number of smaller ones appended to it, placed one below the other, and forming by their aggregation prisms or cylinders: the tentacles, as in Physalia, are of three kinds: some are filiform, beset with thread-cells and cirri, susceptible of much elongation; the others form a racemose cluster at their lower extremity, e. g. in the *Physophora hydrostatica:* some form groups of pyriform or spherical vesicles; a third kind are short and conical, and perform the office of digestion. The sac or body is defended by substances of cartilaginous hardness. Only the external membrane of the air-bladder appears to be perforated in the Physophora. For the description of a compound form of physograde Acalephe, forming the genus *Stephanomia*, I may refer to the excellent paper CXLVI. p. 217.

The genus *Diphyes* presents a long, conical, subangular body of a cartilaginous firmness, closed and pointed anteriorly, with two wide apertures at its base: the upper of these is the outlet of the cavity containing the air-vesicle, and is called the natatorial cavity; the lower orifice is that of the nuclear cavity, from which issues a tubular tentacle, with polypoid organs seated upon it. Within this cavity is usually sheathed a second conical capsule, traversed by the common tube or "chapelet," and having also its air-bladder: in this the ovary or testis is developed. As it enjoys independent movement when separated from the former, it was regarded by Cuvier as a distinct individual, developed by gemmation; and it is homologous with the medusoid individuals similarly developed, and appropriated to the generative function, by ova, in the *Coryne.* The canal into which the stomach opens terminates in a long rounded cavity, lined by a ciliated epithelium.

Two genera of physograde Acalephæ have an elliptic or circular discoid body, supported by an internal cartilaginous or subcalcareous plate. In the circular form called *Porpita* the plate consists of two lamellæ, including a great number of air-canals, the parietes of which are slightly calcified: the prehensile organs are chiefly developed from the margin of the float. In the elliptical *Velella* the horizontal disc consists of four pieces united together by oblique sutures: from the upper surface of the body-disc there rises a second thin semi-elliptic plate, which is set at the same angle to the disc or deck as the lateen sail of the Malay boat. By means of this plate the little Velella is wafted along by the action of the wind, and has probably been often mistaken by navigators for the fabled cephalopodic Paper-sailor (*Argonauta*). Prehensile and digestive tentacula depend from the under surface of the disc, in the centre of which, both in *Porpita* and *Velella*, is a short tube, with an orifice that probably relates to the excretory and respiratory functions.

The Acalephæ propagate by spontaneous fission, by gemmation, and by impregnated ova: the parthenogenetic modes are chiefly limited to the young or larval state. In some species the gemmation is incomplete, and a chain of organically-connected individuals results, as, e. g. in the *Diphyes campanulifera* and the *Stephanomia prolifera*. Both these and the *Physophoridæ* are also oviparous. In the *Diphyidæ* the generative individual commences as a bud or process of the common tube, and, after great changes in its form, becomes provided, like the parent individual, with a natatory organ and with a sac composed of two membranes suspended from its centre. The ova, or the spermatozoa, according to the sex, are developed between the two membranes of the sac; the individual then becomes detached, and swims freely about.

In the Norwegian seas there are little Medusæ, very similar to those called by Eschcholtz *Cytais*, in which Sars observed that gemmation took place from the sides of the pendant stomach; this organ has four sides, and from each of these proceeds a little bud, and these buds are observed in different grades of development: they are successively detached as they attain the form of the parent in miniature, and soon acquire their full size.* In May, 1837, Sars observed a similar gemmation in the *Thaumantias multicirrata*, a (probably larval) Acalephe, one inch in diameter.† In the *Sarsia prolifera* Forbes found the buds produced at the bases of the four marginal tentacles, and hanging from them in bunches. The degree of development is not equal in all the four bunches, and in each case buds are seen in very various stages of development, from embryo wart-like sproutings to miniature medusæ.‡ Will states, that in the *Beroë* (*Eucharis*) *multicornis* he saw the tubercles and lobes occasionally detached, and assuming signs of independent life[*]; swimming freely, and acquiring, with a slight growth, a certain radiated form: but the acquisition of the form of the parent by these buds has not been witnessed. Martens observed small portions of the body of the *Cestum veneris* detached, which moved independently for some time.[†]

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* CLI. p. 10. pl. IV. 7—13.

† Ib.

‡ CXLVII. p. 17.

The most common mode of generation in the completed forms of *Acalephæ* is by the development of ova impregnated by spermatozoa. In certain ciliogrades, e. g. *Eucharis multicornis*, the ova are developed in the common cavity of the body along one side of each longitudinal rib or ridge, and the testes on the other side; so that there are eight rows of ova and eight of testes. An efferent canal extends from each row towards the mouth. This androgynous condition, with the distinct stomach and chylaqueous cavity, indicates the affinity of the Beroïdæ with the Actiniæ. The pulmogrades are highly prolific, and propagate in the ordinary manner by impregnated ova; the germs of which are developed in one set of individuals, whilst the spermatozoa are developed in organs peculiar to other individuals, the Acalephæ of this order being male and female. Gaede first pointed out the ovaria, and described and figured the ova in the medusæ.[‡] Ehrenberg confirmed and added to Gaede's observations of the females; but he thought the spermatozoa of the male medusæ parasitic cercariæ, the testes and ovaria having the same form and colour in the younger medusæ[§]: but they are different in structure, and the males have never the marsupial sacs on the arms.

In *Geryonia* and *Thaumantias* the generative sacs are situated in some part of the canals traversing the disc; in *Aurelia* they are formed by pushing in the wall of the stomach; in *Rhyzostoma* and *Cephea* they are attached to the under wall of the stomach; in *Cyanæa* the organs of generation are situated, in both sexes, in four cavities (*fig.* 71, *e*, *c*,) which push in the walls of the stomach and open on the under-part of the disc, near the mouth. The females of *Cyanæa aurita* are distinguished, at the advanced stage of the breeding season, by the numerous small flask-shaped marsupial sacs which are attached to the under surface of the oral tentacles.

Male medusæ do not differ, in respect of size, from the females. Siebold[||] finds that, when the *Cyanæa aurita* is but 1¼ in. to 1¾ in. long, the males may be distinguished by the sperm-sacs in the tæniiform testis, and the females by the germ-vesicle and spot in the similarly shaped ovaria; but the band-like genital organ is small, and instead of folds, shows only risings and depressions. When the medusæ are still younger, the organ is only a flat band, without inequalities. Each testis consists of a band with many folds ; the whole bent in a bow, with the convexity attached to the concave wall which divides the generative cavity from the stomach.

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[*] CXIV. p. 42.

[†] CLIII. p. 494. tf. i. fig. 2—4.

[‡] CXXXIX. taf. i. fig. 1.

[§] CXL.

[||] LV. p. 6.

If a probe be inserted into the generative cavity, it immediately touches the under or outer surface of the testis; if it be passed into the digestive cavities, it touches the upper or inner surface of the testis, but not immediately, the epithelium of the digestive cavity covering this surface of the testis. The testis is much longer than the cavity containing it, but is adapted thereto by its numerous folds. Its concave side gives off a numerous series of highly irritable coloured tentacles, having the same structure as those on the arms : they are richly ciliated, and contain many hyaline rounded corpuscles and thread-cells immediately beneath the surface. The spermatic tentacles are capable of only moderate extension : at the breeding time they project from the mouth of the generative cavity, leaving only a small passage in their centre. By their powerful ciliary apparatus they keep up a strong current of sea-water in the cavity, and thus aid in the expulsion of the semen. No ciliary movement is observable upon the delicate epithelium covering the lower surface of the testis. The parenchyma of the testis consists of a transparent granular substance in which are imbedded innumerable pyriform sacs, having their basis turned towards the upper surface of the testis, and their apical orifices opening upon the under-surface of the testis, which they make uneven by their tumid margins. The spermatozoa are developed in these sacs, which permanently represent the earliest rudiments of the extremely elongated seminal tubes in higher animals The parietes of the seminal sacs are pretty thick, and, perhaps, contractile.

In young males the sperm-sacs contain numerous cells with many nuclei, from each of which nuclei a spermatozoon is developed; and as this development proceeds, the sperm-cell presents a striated character, and, lastly, a fasciculus of spermatozoa. These have an enlarged end, or body, and a filiform appendage, so fine as scarcely to be seen save by its undulatory movements. The fasciculus of spermatozoa does not exhibit these parts in the same degree of development in each sperm-sac: those nearest the cervix of the sac are the most perfect. The tails of the spermatozoa are always directed towards the opening of the sperm-sac. The bundles of these filaments follow each other, and often the apical tails of one bundle are infixed in the central interspace of the bodies of the preceding bundle, and a chain or string of bundles are thus formed which are easily seen by a moderate microscopic power. These spermatozoa are very lively in sea-water. In order to observe the actual *ejaculatio seminis*, cut off a piece of the testis from a fresh male medusa, place it on a watch-glass with the under surface, on which the sperm-sacs open, uppermost, when if the Acalephe is in the rut, the escape or emission of the spermatozoa may be seen. The development of the sperm-cells is not always according to the size of the animal: they have been found fully formed, in medusæ one inch and three-quarters to three inches broad, and even a specimen of one inch in diameter had active spermatozoa in the testes.

The coloured frill in the generative cavities forms in the female, as in the male, the essential generative apparatus. The ovarium, like the testis, consists of a band, with many folds, attached to the septum dividing the generative from the digestive cavities: it has a proper peristaltic motion; its concave border is beset with similar tentacles, which are extensile and flexible in all directions, are armed with many urticating cells and are beset with vibratile cilia. The thin epithelium on the under surface of the ovarium is here and there slightly ciliated, which has not been observed in the testis. The tissue of the ovarium is looser than that of the testis, and the band has more the appearance of a flattened tube; but the ovarium is not a simple folded sac, with an oviducal opening, as Ehrenberg supposed. The minutest germs of the ova are nearest that surface of the ovarium which is attached to the membranous septum: as the germinal vesicles acquire their vitelline investment they approach the opposite or free surface, from which the mature ova protrude, covered only by a very thin membrane, and giving a coarse granular character to that part of the ovarium. The germinal vesicle has its spot, or nucleus; the surrounding yolk, as it accumulates, becomes violet coloured. It is covered by an extremely delicate membrane with a smooth surface. In this state the ova are transferred from the ovarium to the marsupial sacs; but how they get there is not known; they are doubtless impregnated *in transitu*. In the marsupial ova one can no longer discern the germinal vesicle; it has combined with the matter of the spermatozoa and become diffused through the yolk. The primary germ-cell, developed most probably as in the *Ascaris*, from the impregnated nucleus of the germinal vesicle, attracts the whole germ-yolk about it, and divides it progressively with its own divisions. The first division of the yolk resembles the spontaneous fission of some infusorial monads, inasmuch as it begins, not at every part of the circumference, but on one side (*fig.* 80.), and proceeds across to complete the bipartition (*fig.* 81.). Subsequent subdivisions, corresponding with those of the ova of the *Ascaris* (p. 113.) are described and figured by Siebold, from whose memoir*

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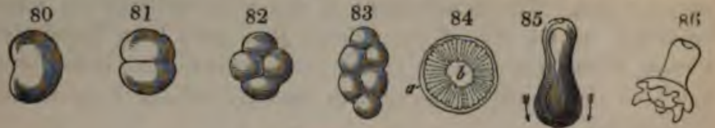
* LV. tab. i.

I have selected the successive two-fold (*fig.* 81.), four-fold (*fig.* 82.), and eight-fold (*fig.* 83.) generation of germ-cells. As the fissures become more numerous, they take a diverging or radiating



Cyanæa aurita.

course, until the whole surface of the ovum presents a granulated character. And now the ovum loses its violet colour and transparency and becomes a dark yellow; it is covered by an epithelium, with traces of cilia; these increase, and at length cover the whole surface, and the new being passes from the condition of an ovum to that of the embryo and obeys the involuntary moving powers. A cavity next begins to be developed in the centre of the germ-cells, which, by continued and reiterated division, take on the form of truncated pyramids, converging towards that centre (*fig.* 84.).

The deep yellow ciliated embryo of the Medusa, which has now a diameter of one eighth of a line, exchanges its rounded for an oval form. It gradually elongates, and takes on a leucophrys-like form, being half a line to one-third of a line in length. At the upper end is a fossa, which does not, however, communicate with the central cavity, and is not a mouth. This stage of development occupies two or three days, when the ciliated monadiform embryo (*fig.* 85.), quits the maternal pouch, and swims forth: the arrows indicate the direction of the ciliary currents. The liberated and locomotive larvæ sometimes re-enter the generative cavity and get entangled between the folds and tentacles of the ovarium, which led Ehrenberg to describe them as ovarian ova; but Siebold observes, that if they were produced there as gemmules with the power of swimming, the marsupial sacs, in which they actually acquire that development, might have been dispensed with.

The great or cephalic end next becomes shortened and thickened, and a depression is observed in its centre, which is the commencement of a digestive cavity; then the margin of this cavity expands, and is developed into four processes, richly furnished with vibratile cilia (*fig.* 86.). A small cavity or disc for adhesion is formed at the opposite extremity of the body, and thus the metamorphosis from the polygastric to the rotiferous form is effected.

The young Medusa, having swam through its infusorial stages, attaches itself to some firm body, preparatory to its next metamorphosis: during which the yellow colour disappears; and the body becomes subtransparent; it also manifests a much more general irritability, the larva sometimes elongating, sometimes contracting itself. Four other tubercles bud out in the interspaces of the first four, and all increase in length. These eight arms have the power of remarkably shortening and lengthening themselves, as exemplified by the two outlines of the same polypoid larva, at *a a* and *b b*, *fig.* 83. Their superficial cilia create vortices in the surrounding water, which carry the nutritive molecules to the mouth of the larva, now metamorphosed into an eight-armed naked and solitary polype. By the subsequent development of new arms from the interspaces of the old ones, a many-armed polype results, and the type of the hydra is exchanged for that of the actinia. The tentacula are very like those of the ovaria and testis in the adult Medusæ; they are ciliated, but not in two regular rows, as in *Flustra* and *Alcyonella*. They contain clear corpuscles, or thread-cells, arranged in regular bracelets, like the tentacles on the margin of the disc of fully developed medusæ. The mouth of the polypoid larvæ is very contractile and expansible: they feed on infusoria and on their infusory-like younger brethren, one-half of the body of one of which may often be seen hanging out of the devourer's mouth. If nourishment be abundant the larval polype propagates by gemmation (*fig.* 88.).

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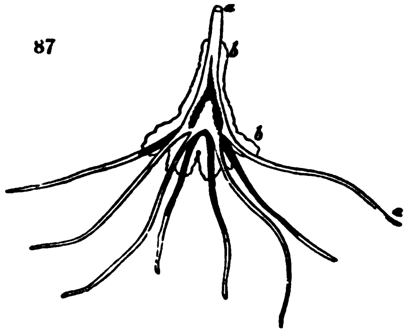
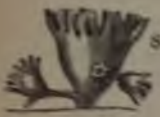


Larval Cyanæa.

Still more remarkable to Siebold was the production in a few of these larvæ of lateral branches from the body, of a great length, — in one case three such stolones were developed. These branches have continuations of the digestive cavity in them, and contract and elongate like ordinary arms. If these were irregularities, and the ordinary metamorphoses were delayed, it was, he conceived, through the influence of captivity. Siebold also thought that the larval medusæ, which in autumn, in open sea, thus change to fixed polypes, hardly would continue in that state through the winter, but about the beginning of the stormy period would change to free-swimming medusæ, and settle down to tranquil depths of ocean. Sir J. G. Dalyell, however, has determined the period of the duration of the polype form of the larval medusæ to be much longer than Siebold conjectured, and he even succeeded in keeping a colony of these larvæ, which he called "hydræ tubæ," for six years.

With regard to the marsupial sacs on the arms of *Cyanæa aurita*, these are attached to the fringed processes on each side of the oral arms. They are developed before the ova quit the ovaria; are largest on the upper and middle part of the arms, while at the undermost part only small and usually empty sacs are found. Do they disappear after the progeny is developed and the breeding season past, or does the parent perish with them when her maternal and nutricial functions have been performed? The membrane from which the sacs are developed is beset on its free edge, both in males and females, with numerous tentacles, similar to those found in the generative or respiratory cavities. Siebold thinks they are more numerous in the male than the female.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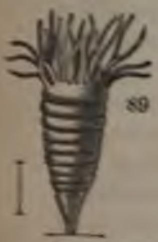
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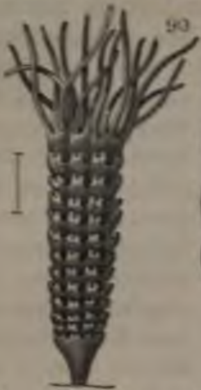
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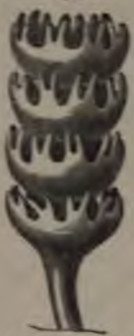
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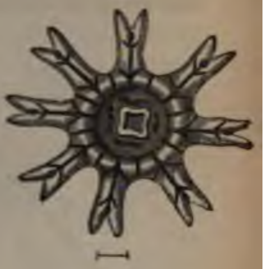
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88. Gemmation of Hydra tuba.
89. Scyphistoma.

90. Strobila.

Spontaneous fission of Strobila.

Ephyra.

The subsequent metamorphoses, or rather metageneses, of the larval medusæ are equally extraordinary with those above described, which the observations of Siebold have mainly contributed to explain. The cycle of these changes is so remarkable, that I feel bound to submit the whole body of evidence, from different and independent witnesses, by which the phenomena have been established and linked together.

It is now sixty years since Otho Fred. Müller first described and figured[*] a marine Polype, which, from its general resemblance to the fresh-water kind, he called *Hydra gelatinosa:* it is the *Hydra tuba*, of Dalyell, or a larval Medusa at the same polypoid stage.

Eschcholtz, in 1829[†], first described a small medusoid animal which he called *Ephyra;* this now turns out to be the penultimate stage of *Cyanæa aurita*.

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[*] CLIV. vol. iii. p. 25. t. xcv.

[†] CLV.

Sars, in 1833, discovered a gelatinous Polype differing from the *Hydra gelatinosa* by its thicker body, slightly marked by transverse rings; believing it to be a new genus of Polype, he described it under the name of *Scyphistoma* (*fig.* 89.). In the same year Sars also described a gelatinous polypoid animal, differing from the above in the deeper annulation of its thicker body, the rings of which developed bifid processes (*fig.* 90.); and he called this very singular creature *Strobila*, from its resemblance to an artichoke. He finally saw the rings or segments separate from one another (*fig.* 91.) and swim off as little medusæ (*fig.* 92.).*

At the meeting of the British Association, at Edinburgh, in 1834, Sir J. G. Dalyell communicated his observations on a marine *Hydra*, which he had called *Hydra tuba*, or the trumpet-polypus; he described it as about five lines long, and with about thirty tentacula, stated that it was very predacious, would gorge young actiniæ, and discharge the rejectamenta again by the mouth. It was very sensitive to light, contracting and retreating from it. It was not very locomotive, and propagated by complete gemmation, the young not removing themselves very far from the parent.

In his later work†, published in 1847, Sir J. Dalyell remarks, "Hence it is natural to assume that a germ, or deposition of elementary matter, subsists somewhere in the flesh," and that "generated within as a compact substance, its way is made, by a regular process, to the exterior, where it becomes visible as a rising prominence." And at page 89. he asks, "Whether the budding results from a germ come of an earlier principle," which shows how nearly the ingenious author had arrived, by independent thought, at the true condition of parthenogenesis.‡

Upon the whole, Dalyell has given us the best history of this polype stage of the Medusa, of its longevity, of its powers of propagation by gemmation, and also its powers of repairing injury. To give an idea of the reproducing force in the *Hydra tuba:* on April 23rd an adult was detached from its site and insulated; in four days a spur or bud had issued from one side of the base, and a large protuberance with a row of papillæ, an originating embryo, was rising from the other. On the 2nd of May these papillæ had elongated into perfect tentacula, like those of the adults. Another protuberance on the opposite side of the parent was now visible, which gradually matured into a young hydra, and began to feed on the 17th. On the 30th of May separation had taken place; four individuals were to be observed, and one was in the progress of developing two others. Dalyell obtained from these a colony of eight larval "hydræ tubæ." These were extremely voracious: they were fed with the flesh of mussels; and in proportion as they were fed was their power of converting their food into creatures like themselves. By July 21st fifteen hydræ were propagated, and ultimately a colony of eighty-three were obtained from the individual insulated on the 23rd of April. It would seem that confinement tended to check the metamorphosis into the "oviparous form," and favoured the gemmation of the polype individuals, or the "typical form." At length, however, in the spring of a subsequent year he observed the phenomena which he thus describes, in the "Edinburgh Philosophical Journal" for 1836: —

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* CLVI.

† CIX. vol. i. p. 82.

‡ First pointed out in LXXXIV. (1843), pp. 234. 366.

"I kept a colony of these animals and their descendants during six years; numbers attained maturity; they fed rapaciously; grew and bred, succeeding at all seasons of the year. But, in February and March, the face or disc of some hydræ is invested by a pendulous flexible prolongation of an inverted conical form, obliterating the tentacula entirely. The apex being connected with the disc, this pendulous mass extends two or three lines in the course of time, and is gradually developed in twenty or thirty successive strata, gradually broadening outwards. When more mature, the vehement clasping of extending arms at the extremity denotes that each stratum is an animated being, which, after excessive struggling, is liberated, to swim at large in the water. This also may be associated with the medusariæ. It is considerably larger than the preceding, two lines in diameter: of a whitish colour, tending to transparence. The body resembles a flattened watch glass; the margin dilating into from five to twelve horizontal, broad, flattened lobes, each cleft half way down the middle, and with a black glandular-looking speck in the centre of the fork. A crest, resembling a quadrangular clustered column, rises from the convex surface of the body, and four organs may sometimes be observed on the same surface near its base. Motion is accomplished in jerks or leaps, somewhat as by the Medusæ proper, from percussion of the lobes on the water, the crest being downwards. Whether the pendulous mass or its individual parts be contained in one common involucrum, or in many specific teguments, is uncertain; but each of the animals composing it comes successively to maturity and departs. As the pendulous prominence disappears, the vigour of the hydra is restored, and the tentacula, liberated of the encumbrance, effecting temporary obliteration, resume their natural form and functions. Weeks elapse in the course of this process, and during survivance of the animals." So that here the observations by Sars, of his *Scyphistoma* (1833), illustrated by those of Dalyell (1836), established a series of metamorphoses carried on from the *Hydra gelatinosa* or *Hydra tuba*, to the medusa state. Our next question, at that date, would have been;—What does this Hydra tuba come from? For this part of the history of the Medusa, we are indebted to Prof. Siebold (1838), who traces the development of the ova of the Medusa (*Cyanæa aurita*) to the Hydra tuba, as has been already detailed; during which, as in *Campanularia*, a ciliated monadiform planula precedes the polype stage; and thus the two detached series of links are united into one harmonious metagenetic cycle.

Confirmation by different observers is not wanting. The accurate Sars, pursuing his researches, followed out, independently, the whole series of changes of the ova of the Medusa, from the infusorial to the polype-type, thence to the scyphistoma and strobila; finally to the budding forth of the flattened segments, and the splitting up into a pile of Medusæ. The details, with figures, were published in 1841.* But Dalyell has shown us that the polype larva may have propagated hundreds of hydræ, before it issues into the pile of Medusæ. The sea which washes our coasts is sometimes covered by millions of these little Medusæ. Dalyell narrates, in his beautiful work, that one summer having selected a specimen of a Medusa of the genus *Chrysaora*, he kept it alive in a capacious jar of sea-water for a few days. On removing it from the jar in which it had been placed, he found that a quantity of brownish matter, like dust, remained at the bottom. Subjected to the microscope this proved to be a host of animated creatures in quick and varied motion; each was of an oval form, ciliated, actively moving, like the planulæ. Some of these, after a period of ten or twelve days, become developed into stationary hydræ.†

Such is the nature of the full and satisfactory evidence on which the main facts of the generation of the Medusæ are established. In comparing different stages of the very interesting development of the *Cyanæa aurita* to Infusories and Polypes, it must be understood that such comparisons are warranted only by a similarity of outward form and of the instruments of locomotion and prehension. The essential internal organisation of the persistent lower forms of the *Zoophyta* is wanting in the transitory states of the higher ones. A progress through the inferior groups is sketched out, but no actual transmutation of species is effected. The young Medusa, before it attains its destined condition of maturity, successively resembles, but never becomes, a Polygastrian, a Rotifer, a Hydrozoon and an Anthozoon.

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* CLII.

† CIX. vol. i. p. 103.

The *Cyanæa aurita* is, however, but the representative of one of the three leading divisions of the remarkable animals grouped together under the name of *Acalephæ*. With regard to the development of the ciliograde and physograde species, scarcely anything connected or precise is at present known. The Medical Officer who may be destined for foreign service, and to whom the study of Nature offers any charm, could hardly contribute observations more valuable to natural history than such as he might be able to make on the generation and development of the Pelagic Acalephæ.

Summary of the Orders and Families of the

Class ACALEPHÆ.

Free swimming marine animals of a gelatinous or membranous tissue with thread-cells. Digestive cavities or canals adherent to the surrounding tissues, and communicating with a more or less ramified chylaqueous system. Most are diœcious, and pass by metagenesis through the forms of the monad and the polype, before acquiring the sexual acalephoid character.

Order PULMOGRADA. (Medusæ.)

Body discoid, with a marginal velum, and a central inferior mouth, usually prolonged into a more or less complex proboscis. ***Locomotion*** by rythmical contractions of the disc. Sexes distinct.

Suborder GYMNOPHTHALMATA. (Bare-eyed Medusæ.)

Cysticles unprotected: ***Chylaqueous canals*** simple, or, if ramified, not anastomotic. Gemmiparous. (Some are probably larvæ.)

Families	*SARSIIDÆ.*	Chylaqueous canals simple, four: ovaries in the substance of the proboscis. Genera: ***Sarsia***, ***Euphysa***, ***Steenstrupia***.
	GERYONIIDÆ.	Chylaqueous canals simple, four: ovaries beneath the disc. Genera ***Geryonia***, ***Thaumantias***, ***Slabberia***.
	CIRCEIDÆ.	Chylaqueous canals simple, eight: ovaries eight, beneath the disc. Genus ***Circe***.
	ÆQUOREIDÆ.	Chylaqueous canals simple, eight or more: ovaries linear on the course of the canals beneath the disc. Genera ***Polyxenia***, ***Stomotrachium***, ***Æquoria***, ***Phorcunia***.

Families *Oceanidæ.*	Chylaqueous canals simple: ovaries convoluted, and lining the pedunculated stomach. Genera *Oceanea, Saphenia, Turris, Cytaeis.*
Willsiidæ.	Chylaqueous canals branched. Genus *Willsia* *, *Berenix, Orythia.*

Sub-order STEGANOPHTHALMATA. (Clothed-eyed Medusæ.)

Cysticles protected by complicated coverings: *Chylaqueous canals* canals branched and anastomotic. No gemmation.

Families *Rhizostomatidæ.*	Mouths numerous on the branches and borders of a ramified proboscis. Chylaqueous canals without outlets. Genera *Rhizostoma, Cephea, Cassiopæa.*
Monostomatidæ.	Mouth single : Chylaqueous canals, (in some) with distinct outlets. Genera *Phacellophora, Cyanæa, Pelagia, Chrysaora, Aurelia.*

Order CILIOGRADA.

Body spheroidal, oblong, or lobated, rarely lamelliform. *Locomotion* by longitudinal bands of cilia. Sexes, in some, combined.

Families *Beroidæ.*	Genera *Beroë, Lesueuria, Medea, Cydippe, Pleurobrachia.*
Mnemeidæ.	Genera *Mnemia, Eucharis, Janira, Alcinoë, Bolena.*
Callianiridæ.	Genera *Callianira.*
Cestidæ.	Genera *Ocyroë, Cestum.*

Order PHYSOGRADA.

Body, floated by air-cells. *Locomotion* by parts exposed to and acted upon by the winds. Nutrition by numerous suctorial tubes.

Families *Diphyidæ.*	Genera *Diphyes, Ersæa.*
Physophoridæ.	Genera *Physophora, Stephanomia.*
Physalidæ.	Genera *Physalia.*
Velellidæ.	Genera *Velella, Rataria, Porpita.*

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* CXLVII. p. 17.

LECTURE X.

ECHINODERMATA.[*]

THE soft and gelatinous Radiaries have often baffled the anatomist by the seeming simplicity and uniformity of their texture; the harder, spine-clad, or Echinodermal species, perplex the most patient and persevering dissector by the extreme complexity and diversity of their constituent parts.

This class of animals, the organisation of which will be explained in the present Lecture, includes species in which the form is most strictly or typically radiate: in it, also, the *Zoophyta* of Cuvier attain their highest conditions of organisation. With a radiated filamentary system of nerves is combined not only a distinct abdominal cavity with an alimentary canal suspended therein by a vascular mesentery, and having a distinct anal outlet, but there are distinct vascular and chylaqueous systems together with a large and well-defined respiratory organ. This organ, however, may be regarded as the exceptional condition of the radiated type of structure, and is found only in the highest and aberrant forms of the present class, which indicate the transition from the Echinoderms to the Annelides. At the opposite extreme of the class, the digestive sac (*fig.* 93, *a*), though suspended freely in an abdominal cavity, has yet but one aperture common to the reception of food and the ejection of excrement. These anenterous Echinoderms (*Ophiuridæ*, *Luidea*, *Asterias* proper, *Astropecten*,) belong to the order *Asteroidea*[†], in which the radiated form is most complete and general, whence the species have received the common appellation of "star-fishes," and "sea-stars."

The almost extinct order *Crinoidea*, in which the radiated body is supported on a jointed and rooted stem, is connected with the order *Asteroidea* by the genus *Comatula*, which in its last stage becomes free.

In certain starfishes (*Asteroidea*) we trace a shortening, flattening, and expansion of the rays, until the body assumes a pentangular discoid form.

In the next order (*Echinoidea*), the angles disappear, and the disc expands until a spheroid or globular form is obtained, which characterises the Echinoderms commonly called "Sea-urchins," and *Echinoi* by the Greeks.

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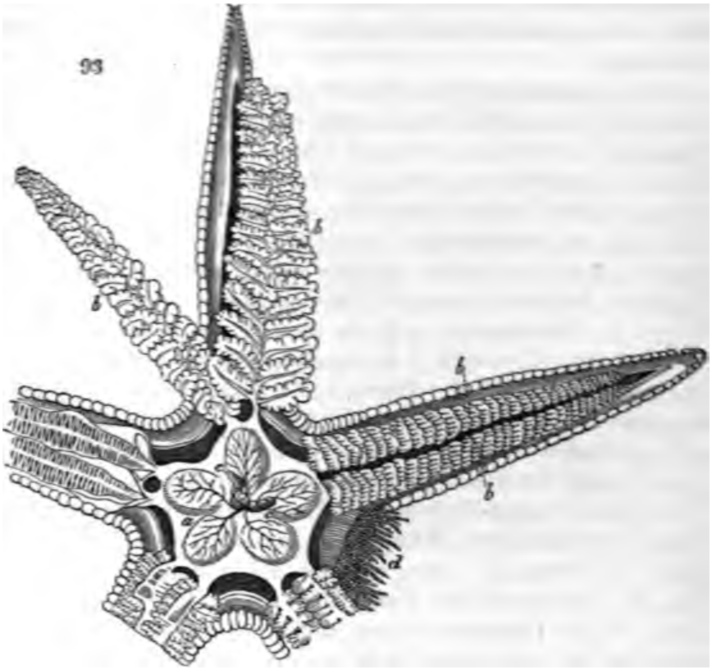
[*] εχινος a hedge-hog, δερμα skin.

[†] See the "Summary" at the conclusion of the Lecture, for the characters of this and other orders of the class.



Asterias.

The Echinoderms of the order *Holothurioidea* may be described as being constituted by a softening of the calcareous skin of the spheroidal species, and by the reduction of the earthy matter to a greater or less number of reticulate calcareous corpuscles, the globe being then drawn out by the two opposite poles into an elongated cylindrical form. These vermiform Echinoderms seem to lead, by the concluding order *Sipunculoidea*, to the true worms, which stand on the lowest step of the Articulate division of the Animal Kingdom.

The name *Echinodermata* has been applied to these diversified forms of the higher organised Zoophytes of Cuvier, because in many of the species the integument is defended by spines: they, however, possess, and are associated together by, another and more general tegumentary character; the skin is perforated in most of the species by minute foramina, through which a multitude of small tubes or hollow suctorial tentacles ('tube-feet') can be protruded and retracted, and these constitute the common organs of adhesion and locomotion in the Echinoderms.

In the aberrant *Sipunculoidea* the tube-feet are wanting, together with the calcareous corpuscles, the worm-like form and annulation of the integument are more decided, but the chylaqueous fluid continues to be agitated in the abdominal cavity by the cilia of the lining membrane.

Before commencing the demonstration of the anatomy of the *Asteroidea*, I may point out the chief characters of the allied order *Crinoidea*, in which the radiated disc is fixed by a long jointed calcareous stem to some foreign body, as they are shown in the existing species, called *Pentacrinus Caput-Medusæ*, the type of a very numerous assemblage of analogous pedunculated star-fishes, which existed in countless myriads during some of the ancient (secondary) periods of geology. Those species in which the stem is cirrigerous and pentagonal, as in the recent form, are called "Pentacrinites:" those in which it is rounded, and seems to have been devoid of cirri, are called "Encrinites." Both kinds have received the common name of "stone-lilies." Their remains sometimes constitute extensive tracts of marble-limestone. The Melocrines are more especially the crinoid prototypes of the *Stelleridæ*.

The stem of a stone-lily is composed of numerous joints or segments having a central aperture, which, when separated, are called "wheel-stones," or "entrochi:" casts of their cavity remaining after the calcareous wall have been dissolved away constitute the "screw-stones" of the Derbyshire chert, and other transition limestones. The jointed column supports at its summit a series of plates forming a cup-like body, containing the viscera, and from the margin of the cup proceed five jointed arms, which radiate and divide into delicate tentacula. The upper side of the arms support numerous short jointed cirri or pinnules. Groups of five long and slender cirri radiate at nearly equidistant points from the stem of the recent species of Pentacrinus. Both the arms and pinnules are grooved along their ventral side, which groove is bridged over by a membrane called "perisome."

The form of star-fish to which the radiated capital of the crinoideal column bears most resemblance is that which is presented by the species of *Comatula*, the ova of which have been discovered by Dr. V. Thompson* to pass through a pedunculated pentacrinite state, before their final metamorphosis into a free star-fish. In the condition of their digestive system the Pentacrinites and Comatulæ correspond with the fettered Bryozoa among the polypes. The free Comatula is a step in advance, and manifests its affinity to the gelatinous Radiaria by its mode of swimming: the movements of its pinnate arms exactly resemble the alternating stroke given by the Medusa to the liquid element, and with the same effect of raising the animal from the bottom, and propelling it back foremost.

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* CLVIII. p. 295.

The rays of the ordinary star-fishes are not cirrigerous or bifurcated: their soft external integument is supported by a tough coriaceous membrane, strengthened by calcareous matter (*fig.* 94.), disposed in a coarsely reticulate form upon the dorsal and lateral aspects of the radiated body, and arranged in series of more compact and regularly-formed transverse pieces, *a*, *b*, which bound each side of a longitudinal furrow, extending along the under surface of each ray from its attached to its free extremity. The sides of this groove are perforated by alternating rows of minute fissures, and external to these are situated the largest and most numerous spines.

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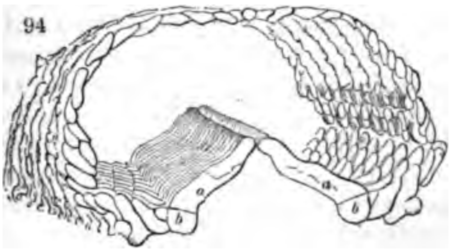

Section of ray of Asterias rubens, showing arrangement of calcareous pieces.

The tube-feet are protruded, in two (*Ast. aurantiaca*) or four (*Ast. rubens*, *fig.* 95 *c*, *c*) rows, through the marginal pores of the furrows, which are termed "ambulacra." These tube-feet have muscular parietes, and they communicate with internal vesicles, *d*, *d*, full of fluid, which form, in fact, the bases of the feet. By the contraction of the parietes of the vesicle the fluid is injected into the tube-foot, *c*, *c*, and protrudes and extends it: when the muscular parietes of the tube-foot contract, the fluid is returned into the sac, and the tube-foot is shortened and retracted. The basal vesicles are in communication with, and are supplied by, a system of vessels, *i*, small brown sacs, *m*, and larger pendent pyriform sacculi, which are lodged in the central disc or body of the star-fish, and surround the oral aperture, *a*.

There are other kinds of soft contractile appendages to the integument, some tufted, others of simple form; but the tube-feet just described are the most important organs for prehension and locomotion. The tegumentary processes called "pedicellariæ," which resemble miniature pincers, will be more particularly described in connection with the skeleton of the Echinus. In the star-fishes they are of the kind called *Pedicellariæ forcipatæ* and *Pedicellariæ valvulatæ*.

Various are the forms of the calcareous parts which strengthen and defend the skin of the star-fishes; but in all the echinoderms in which the hardening earth is present, its ultimate arrangement is a fine network, the microscopic meshes or areolæ being more or less circular.

In the genera *Oreaster* and *Culcita* the whole surface is beset with tubercles and granules. In *Asteropecten* and *Stellaster* there are moveable flat spines and marginal plates. In *Solaster* and *Chætaster* there are innumerable spines, the summits of which are beset with setæ. The sides of the arms in *Ophiocoma* and *Ophiomastix* are defended by smooth spines; in *Ophiothrix* by bristled spines. In *Ophionyx* there are moveable double hooks beneath the bristled spines.

The ultimate muscular fibres in the Asteroids are smooth. The joints of the arms and pinnules of the Crinoids and Comatules are moved by a pair of small muscles on their ventral aspect, antagonised by elastic bands. The spaces between the joints of the skeleton of the Asteroids are occupied by muscular fibres, which are antagonised by the general elasticity of the integument. In the Crinoids the margins of the ventral grooves extending from the mouth along the soft perisome are beset with very delicate cylindrical muscular feet, and the surface of each foot is beset with small clavate tentacules. In the *Ophiuridæ* at the sides of the arms there are poriferous plates, out of which protrude cylindrical obtuse feet, covered by a quantity of wart-like protuberances. In this family the rays are extremely attenuated and elongated, and have no ambulacral grooves: nor is the complicated mechanism of the ambulacral feet in the ordinary star-fishes here needed, for the flexile and spinous rays can twine round and seize other objects so as to perform directly the offices of prehension and locomotion. The facility with which an *Ophiura* or *Luidia* casts off a ray which may be touched, and even all the rays, leaving only its central disc, when it is seized, is very surprising; it is consequently very difficult to preserve specimens of these genera entire. To do this it is recommended to plunge them suddenly into fresh water, when they instantly die in a state of the most rigid extension.

According to Müller there extends along the tentacular groove of the perisome on the ventral side of the body of the Crinoids a nervous chord, which forms a slight enlargement at the base of each pinnule, to which a filament is sent. In the *Ophiuridæ* the nervous chords are lodged in a canal protected by the ventral plates of the arms. The soft labial membranes, tentacles, and tubular feet seem adapted to a delicate reception of impressions; and so far as these may be felt by the individual, and cause voluntary movements, such parts may be regarded as organs of touch. The nervous system of the Asterias (*p.* 14., *fig.* 4.) consists of a slender white chord surrounding the mouth (g) immediately exterior to the circular chylaqueous vessel: from this nervous ring three delicate filaments are sent off opposite

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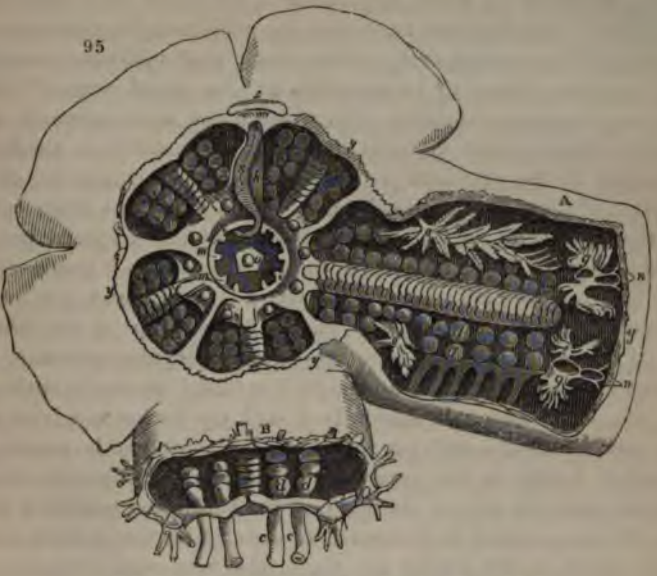

Section of Asteracanthion rubens, showing the tubular feet.

the base of each ray: the lateral filaments enter the discoid body: the middle one is continued along the ambulacral groove, and swells, according to Ehrenberg, into a small terminal ganglion, immediately behind that bright-coloured speck at the extremity of the ray which the same acute observer regards as a rudimental organ of vision (b).

This pigmental organ manifests itself at the earliest appearance of the arms, when they form five marginal lobes of the discoid body of the young star-fish, and give it the pentagonal form which is retained throughout life in the *A. discoidea.*[*]

It is objected by the laborious Siebold that no dioptric apparatus (keine deutliche lichtbrechende Körper) is connected with the pigment-speck; nor has any better reason been given for the visual function of that speck than its relation to a subjacent mass of nervous matter, the analogy of the accumulation of pigmental matter in the choroid of true eyes, the position of the pigment-specks at the forepart of the body in Rotifers, Planariæ, Borlasiæ, Leeches, &c., and the obvious proof that such simple pigment-speck must absorb those rays was in the progress of developing two others. Dalyell obtained from these a colony of eight larval "hydræ tubæ." These were extremely voracious; they were fed with the flesh of mussels; and in proportion as they were fed was their power of converting their food into creatures like themselves. By July 21st fifteen hydræ were propagated, and ultimately a colony of eighty-three were obtained from the individual insulated on the 23rd of April. It would seem that confinement tended to check the metamorphosis into the "oviparous form," and favoured the gemmation of the polype individuals, or the "typical form." At length, however, in the spring of a subsequent year he observed the phenomena which he thus describes, in the "Edinburgh Philosophical Journal" for 1836: —

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[*] CLXIV. p. 172.

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* CLII.

† CIX. vol. i. p. 103.

The mouth in the star-fishes is situated at the middle of the under surface of the body: it is edentulous, and leads by a short wide gullet into a large stomach (*fig.* 93, *a*), which, in the *Stelleridæ*, sends off a pair of sacculated cæcal appendages (*bb*) into each of the rays, but is without intestine or anus in *Ast. aurantiaca* (*Asteropecten*). The small terminal pouches of these appendages appear to secrete a substance subservient to chylification: two or more small glandular sacs (*cc*) of a yellowish colour open into the bottom of the stomach, and have been regarded as a rudimental form of liver. In *Asteracanthion*, *Asterogonium* and *Solaster*, there is a short intestine with an anal opening, opposite to the mouth; and in these there are inter-radial cæca, which in *Asteracanthion rubens* contain a brownish fluid, in which uric acid has been detected. Each long sacculated

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* CLXV. p. 253.

† "Die von Forbes (History of Star-fishes, p. 139.) mitgetheilte Erzählung, wie *Luidia fragilissima* durch freiwilliges Abtrennen der Arme, mit spöttisch blinzelnden Augen ihren Verfolger anblickend, sich der Gefangenschaft zu entziehen wusste, ist recht anziehend zu lesen, kann aber natürlich nichts über das Dasein von Augen bei den Seesternen entschieden." XXIV. p. 88.

Families	*OCEANIDÆ.*	Chylaqueous canals simple: ovaries convoluted, and lining the pedunculated stomach. Genera ***Oceanea, Saphenia, Turris, Cytaeis.***
	WILLSIIDÆ.	Chylaqueous canals branched. Genus ***Willsia**, *Berenix, Orythia.***

Sub-order STEGANOPHTHALMATA. (Clothed-eyed Medusæ.)

Cysticles protected by complicated coverings: ***Chylaqueous canals*** canals branched and anastomotic. No gemmation.

Families	*RHIZOSTOMATIDÆ.*	Mouths numerous on the branches and borders of a ramified proboscis. Chylaqueous canals without outlets. Genera ***Rhizostoma, Cephea, Cassiopæa.***
	MONOSTOMATIDÆ.	Mouth single: Chylaqueous canals, (in some) with distinct outlets. Genera ***Phacellophora, Cyanæa, Pelagia, Chrysaora, Aurelia.***

Order CILIOGRADA.

Body spheroidal, oblong, or lobated, rarely lamelliform. ***Locomotion*** by longitudinal bands of cilia. Sexes, in some, combined.

Families	*BEROIDÆ.*	Genera ***Beroë, Lesueuria, Medea, Cydippe, Pleurobrachia.***
	MNEMEIDÆ.	Genera ***Mnemia, Eucharis, Janira, Alcinoë, Bolena.***
	CALLIANIRIDÆ.	Genera ***Callianira.***
	CESTIDÆ.	Genera ***Ocyroë, Cestum.***

Order PHYSOGRADA.

Body, floated by air-cells. ***Locomotion*** by parts exposed to and acted upon by the winds. Nutrition by numerous suctorial tubes.

Families	*DIPHYIDÆ.*	Genera ***Diphyes, Ersæa.***
	PHYSOPHORIDÆ.	Genera ***Physophora, Stephanomia.***
	PHYSALIDÆ.	Genera ***Physalia.***
	VELELLIDÆ.	Genera ***Velella, Rataria, Porpita.***

* CXLVII. p. 17.

fluid to the vesicles at the base of the hollow tentacles protruded through the ambulacral pores. Tiedemann and Sharpey [*] also agree in rejecting the continuation of the chylaqueous or erectile system of the feet from the intestinal vascular system. In the Crinoids a cordiform sac lies at the bottom of the cup-shaped body, from which vessels diverge along the axial canal of the arms, pinnules, and cirri, and a vessel descends into the spongious axis of the body-cavity and stem. A chylaqueous canal, which runs immediately beneath the tentacular furrow, conveys the fluid to the hollow feet: in the Comatula the canal is divided by a medi-vertical septum. In the *Ophiuridæ* two or four broad respiratory lamellæ project from each of the five inter-radial angles into the visceral interspace.

In some star-fishes there is a small membranous tube, filled with calcareous particles, called by Tiedemann the sand-canal: its position is indicated by the circular multiperforate prominence or nucleus (*fig.* 95, *z*), on the dorsal aspect of the disc of the Asterias, near the angle between two of the rays, which prominence resembles a miniature brain-stone madrepore. In other *Stelleridæ* a jointed calcareous column (*fig.* 95, *s*), is continued from the nucleus into the interior of the body, and consists of minute hexagonal plates, which are united into larger joints. The precise function of these appendages to the nucleus is not yet understood. From the analogy of one of its modifications with the jointed column of the crinoid star-fishes, it has been suggested that it may be the analogue or remnant of that column; but, according to the observations of M. Sars, the Asteriæ are not fixed animals in the young state. Dr. Sharpey has conjectured that it may serve as a filter in the admission of sea-water to the tubular system of the ambulacral feet: and it unquestionably relates to the chylaqueous system, of which it is a part distinguished by the calcareous deposits superadded to the canal. The sand-canal is adherent to the parietes of the body in the *Ophiuridæ* and *Echinidæ* as well in the *Stelleridæ*: but the spot to which it adheres in the *Ophiuridæ* is imperforate. In the *Holothuriadæ* it hangs loose in the abdominal cavity. In the *Asterophyton* the madreporoid nucleus is situated on the ventral aspect of the disc.

As the sea-water is freely admittèd into the general cavity of the body, and bathes all the viscera, their vascular surfaces thus stand in the relation of a respiratory organ to the aerated medium, and they are every where provided with vibratile cilia, which maintain the currents of oxygenated fluid.[†] But with the sea-water is mingled a kind of chyle-corpuscles, long since recognised by Erdl[‡], the forms of which in different Echinoderms have been lately described by terises the Echinoderms commonly called "Sea-urchins," and *Echinoi* by the Greeks.

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[*] CLX. p. 35.

[†] CLXI.

[‡] CLXII. p. 58.

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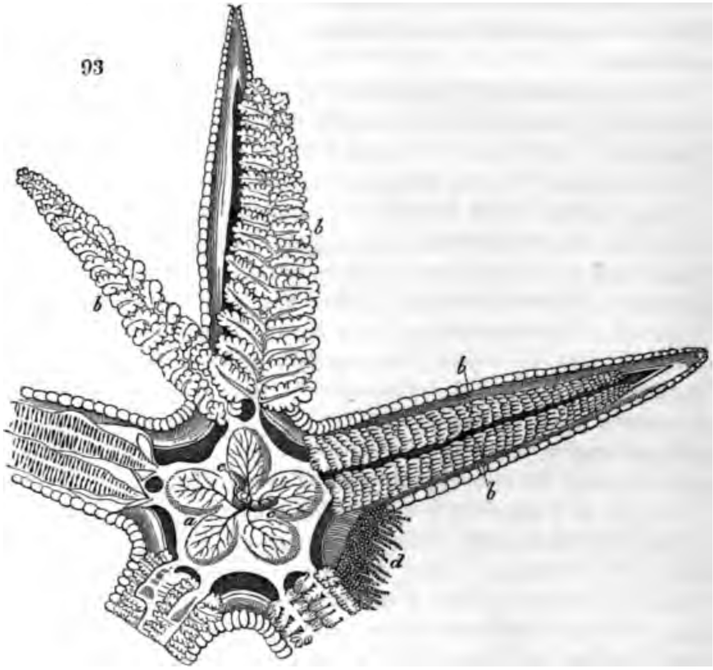

Asterias.

The Echinoderms of the order *Holothurioidea* may be described as being constituted by a softening of the calcareous skin of the spheroidal species, and by the reduction of the earthy matter to a greater or less number of reticulate calcareous corpuscles, the globe being then drawn out by the two opposite poles into an elongated cylindrical form. These vermiform Echinoderms seem to lead, by the concluding order *Sipunculoidea*, to the true worms, which stand on the lowest step of the Articulate division of the Animal Kingdom.

The name *Echinodermata* has been applied to these diversified forms of the higher organised Zoophytes of Cuvier, because in many of the species the integument is defended by spines: they, however, possess, and are associated together by, another and more general tegumentary character; the skin is perforated in most of the species by minute foramina, through which a multitude of small tubes or hollow suctorial tentacles ('tube-feet') can be protruded and retracted, and these constitute the common organs of adhesion and locomotion in the Echinoderms.

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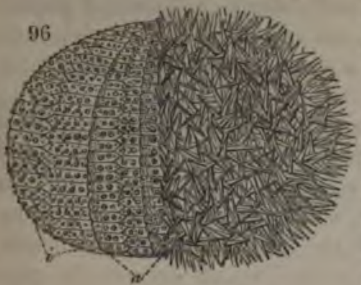

Echinus.

which constitute a hollow spheroid, having a large aperture at each pole, where the first four kinds of plates are situated. The ambulacral plates (*a*) are perforated for the passage of the tubular feet, the parallel rows of which intercept and overshadow spaces compared by Linnæus to avenues or ambulacra; these plates likewise support spines. The interambulacral plates, (*i*) which support a greater number of the spines, are characterised by more numerous tubercles, and are not perforated. Both kinds of plates are of a pentagonal form, and are arranged each kind in five alternate pairs of vertical rows. The plates of each pair are united together by a zigzag suture, and increase in size as they approach the equator of their living globe. These twenty series of ambulacral and interambulacral plates constitute the chief part of the spheroidal skeleton of the Echinus. The large oral aperture is partly occupied by the small irregular oral plates, which have no tubercles or spines, and are suspended in the oral integument, from the middle of which project the points of the five teeth. At the opposite aperture, immediately surrounding the vent, are the small anal plates; external to these are the five genital or oviducal plates, so called because each is perforated by the duct of an ovarium or testis; the ocular plates are wedged into the external interspaces of the genital plates, and are pierced near the apex by a very minute pore, which lodges the ocellus and its little nerve.

One of the genital plates is larger than the rest, and bears a tubercle corresponding with the nucleus or madreporiform tubercle on the back of the star-fish. M. Agassiz, assuming this plate to be at the back part of the Echinus, showed that the other four genital plates were in symmetrical pairs, and thus discovered the right and left sides of the animal.

The calcareous constituent of the shell of the *Echinus lividus* has the following chemical composition, according to the analysis of Professor Brunner, quoted by Professor Valentin.*

Carbonate of lime - -	96·27
Sulphate of lime - -	1·53
Carbonate of magnesia -	0·93
	100·00

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* CLXVII.

The small anal plates are united together like the oral ones by an extensile and contractile membrane. Both the internal and external surface of the rest of the complicated shell is covered by a similar organised membrane, which likewise extends through all the numerous sutures of the shell. With this explanation of the general structure of the crust of the Echinus we are in a condition to understand the manner of its growth, which otherwise would be a difficult physiological problem.

The Echinus maintains nearly the same spheroidal figure from its earliest formation to full maturity; and, notwithstanding that its soft parts are almost entirely confined by a fragile and inflexible globular crust, this is never shed and reproduced, like the shells of the crab and lobster. At the same time the calcareous plates possess not more power of inherent growth than do the crusts of the Crustacea. By the subdivision of the hollow globe into many pieces, and the apposition of a formative membrane to all their margins, addition is made to the circumference of each component plate, and by the plan of their arrangement the spheroidal shell gradually expands, with little change in its figure and relative proportions.

The amount of change in the form of the shell, which differs in different species, depends upon the addition of new plates to the ambulacral and interambulacral series. These are developed near the oral and anal poles, but chiefly near the latter, where, in the young *Cidaris*, for example, the plates are more loosely connected together, and support incomplete spines. In the membrane connecting such plates may be seen small irregular pieces, without tubercles or spines, which grow by accretion to their margins, and then have the tubercles developed upon their outer surface. The spines are at first immoveable, and stand out like processes from the tubercle; the joint is not developed until after they have acquired a certain size. The growth of the globe in the direction of its poles is chiefly by the development of the new plates; its expansion at the equator is by the addition to the sutural margins of the old plates. In full grown and aged specimens, especially of *Scutella* and *Clypeaster*, the sutures become obliterated.

The spines of the *Echini* vary in form and relative size in different genera; in each the proximal extremity is adapted, by an excavation, to one of the tubercles on the outer surface of the plate, to which it is attached by a capsular ligament, and upon which it can be rotated by muscular fibres external to the capsule. In the species of *Cidaris*, where the spines are unusually large, an internal ligament extends from a little pit upon the centre of the tubercle to the centre of the articular cavity of the spine, analogous to the round ligament in the hip joint. The spines grow by successive additions, through calcification of that part of the common organised membranous covering of the shell of the Echinus, which is attached to their base. The varied areolar organisation of the spines affords beautiful microscopical objects when viewed in thin transverse slices.

In the typical genera, *Echinus* and *Cidaris*, e. g. the ambulacral pores extend from pole to pole; but in *Scutella* and *Rotula* they are confined to the dorsal aspect of the more flattened spheroid, where they form a five-leaved rosette.

The tube-feet that issue from the ambulacral pores can be extended beyond the longest spines in the *Echinus Sphæra* of our own coasts; they terminate in suckers, which appear to be highly sensitive, and by which the Sea-urchin attaches itself to foreign bodies, and moves along them with a rotatory course, with its mouth downwards, the spines serving to balance and direct the progress of the animal. The bases of the tube-feet communicate with the cavities of the internal vesicles or branchiæ (*fig.* 98, *g*); their outward surface is ciliated. The terminal sucker of the tube-foot is supported by a circle of five or, sometimes, four reticulate calcareous plates, which intercept a central foramen, and by a single delicate reticulated perforate plate on the proximal side of the preceding group. The centre of the suctorial disc is perforated by an aperture conducting to the interior of the ambulacral tube-foot.

I have reserved the notice of another class of appendages to the integument, not only of the Echini, but of the Asteriæ, for this part of my discourse, because they are most developed, most varied in structure, and have been most minutely investigated in the species of the globular family of Echinoderms. The appendages to which I allude are called "pedicellariæ," and consist of a dilated end or head, usually prehensile, supported by a slender stem or pedicel. They present different forms, which hold constant and determinate positions in the crust of the Echinus: they seem at no season to be absent, and must therefore form part of the integral organisation of the Echinoderm. They have, however, been conjectured by some naturalists to be parasitic animals; by others to be the young of the Echini, to which they are attached.

In the *Ech. lividus*, Professor Valentin, to whom we owe the most minute descriptions of these bodies, divides them into gemmiform, tridactyle, and snake-headed pedicellariæ. They are all composed of an internal calcareous axis, and a soft external tissue.

The gemmiform pedicellariæ* are placed around the tubercles, especially the largest ones: their pedicel is long and slender; their capital resembles the bud of a flower, defended by three sepals, the apex of each of which is produced inwards in the form of two pairs of long and slender teeth. The quadridentate sepaloid plates can be divaricated and approximated, and constitute a very effective prehensile instrument: they are highly irritable; a needle introduced into their grasp is instantly seized. The ciliated gemmule of any parasitic coralline, which might settle about the base of a spine, and there commence its growth, would be liable to be seized and uprooted by the prehensile gemmiform pedicellariæ, which are of microscopic minuteness.

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* *Pedicellariæ globiferæ*, Muller.

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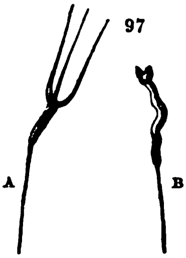

Pedicellariæ.

The tridactyle pedicellariæ (*fig.* 97, A) are of larger size, are visible to the naked eye, and fit to grapple with and dislodge young sedentary parasites of larger species, as Cirripeds and Conchifers. They are found more particularly around the large tubercles of the interambulacral plates which support the largest spines. Their capital is longer, narrower, and more pointed than in the gemmiform kind; and the three pieces are dentated and close upon each other, like the blades of pincers.

The "pedicellariæ ophicephalæ" are aggregated principally upon the buccal membrane.

The pedicellariæ of the star-fishes are diffused generally over the surface, and form dense groups round the spines: they consist of a slender contractile stem; but the head resembles a forceps with two blades (*fig.* 97, B): they are continually in motion, opening and shutting their blades. They would wage as effective and serviceable a war in defence of the integument of the Asterias against the attacks of the host of parasites which the sea engenders as their tridactyle analogues in the Echini may do. In some species of *Goniaster* the pedicellariæ resemble the vane of an arrow, and are so numerous as to give a villous appearance to the integuments.

The muscular system of the Echinus, into the details of which the limits of the present lecture forbid me to enter, includes the muscles of the spines, those of the jaws or lantern, of the buccal membrane, of the anus, of the ambulacral tubes, of the internal branchiæ, and of the pedicellariæ. The muscles of the lantern and spines have their ultimate filaments collected into primitive fibres or fascicles, which are marked by transverse striæ at regular distances as in the muscles of insects.*

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* CLXVII. p. 101.

the hardening earth is present, its ultimate arrangement is a fine network, the microscopic meshes or areolæ being more or less circular.

In the genera *Oreaster* and *Culcita* the whole surface is beset with tubercles and granules. In *Asteropecten* and *Stellaster* there are moveable flat spines and marginal plates. In *Solaster* and *Chætaster* there are innumerable spines, the summits of which are beset with setæ. The sides of the arms in *Ophiocoma* and *Ophiomastix* are defended by smooth spines; in *Ophiothrix* by bristled spines. In *Ophionyx* there are moveable double hooks beneath the bristled spines.

The ultimate muscular fibres in the Asteroids are smooth. The joints of the arms and pinnules of the Crinoids and Comatules are moved by a pair of small muscles on their ventral aspect, antagonised by elastic bands. The spaces between the joints of the skeleton of the Asteroids are occupied by muscular fibres, which are antagonised by the general elasticity of the integument. In the Crinoids the margins of the ventral grooves extending from the mouth along the soft perisome are beset with very delicate cylindrical muscular feet, and the surface of each foot is beset with small clavate tentacules. In the *Ophiuridæ* at the sides of the arms there are poriferous plates, out of which protrude cylindrical obtuse feet, covered by a quantity of wart-like protuberances. In this family the rays are extremely attenuated and elongated, and have no ambulacral grooves: nor is the complicated mechanism of the ambulacral feet in the ordinary star-fishes here needed, for the flexile and spinous rays can twine round and seize other objects so as to perform directly the offices of prehension and locomotion. The facility with which an *Ophiura* or *Luidia* casts off a ray which may be touched, and even all the rays, leaving only its central disc, when it is seized, is very surprising; it is consequently very difficult to preserve specimens of these genera entire. To do this it is recommended to plunge them suddenly into fresh water, when they instantly die in a state of the most rigid extension.

According to Müller there extends along the tentacular groove of the perisome on the ventral side of the body of the Crinoids a nervous chord, which forms a slight enlargement at the base of each pinnule, to which a filament is sent. In the *Ophiuridæ* the nervous chords are lodged in a canal protected by the ventral plates of the arms. The soft labial membranes, tentacles, and tubular feet seem adapted to a delicate reception of impressions; and so far as these may be felt by the individual, and cause voluntary movements, such parts may be regarded as organs of touch. The nervous system of the Asterias (*p.* 14., *fig.* 4.) consists of a slender white chord surrounding the protruded and retracted by certain muscles, which have their fixed points of attachment in five calcareous ridges and arches which project from the inner surface of the plates near the margin of the oral vacancy of the shell. These processes are short in *Clypeaster*, and obsolete in *Spatangus*. For the particular description of these masticatory muscles, which are classed under the following heads—1. Musculi interarcuales, s. comminutores ciborum, 2. Musculi arcuales, s. dilatores orificii dentium, 3. Musculi interpyramidales (sphincter oris), 4. Musculi transversi,—I must refer to the *Leçons d'Anatomie Comparée* of Cuvier (CLXVII.), the Article by Professor Sharpey (CLX. *p.* 38, *fig.* 17.), and the monograph of Professor Valentin, already cited.

The pharynx occupies the cavity of the lantern, and is divided by five longitudinal folds, most prominent at their commencement; the small salivary cæca are placed close to its continuation with the œsophagus, from which it is separated by a marked constriction. A slender œsophagus (*c*, *fig.* 98.), conducts to the gastric or cæcal portion of the intestine (*d*); and that canal twice performs the circuit of the abdominal cavity before its final termination. The vent, its membrane, and the anal plates, have appropriate muscles for constriction and dilatation. The intestine is generally found more or less loaded with fine sand; its surface and that of its mesentery is covered with a rich vascular network, which conveys the nutrient fluid eliminated from the organic particles swallowed with the sand, to a large vessel or vein, which accompanies the intestine from the anus to the mouth, where it terminates in the vascular circle around the œsophagus, from which the arteries are given off for the supply of the whole body.

In the Spatangus a moderately long cæcum is developed from the first coil of the intestine. In the Clypeaster there are several shorter lateral cæca; and both these and the convolutions of the heavily-laden alimentary canal are supported by peritoneal lamellæ from the inner surface of the shell.

The sea-water is admitted into the peritoneal cavity, and its constant renovation over the surface of the vascular membranes of the Echinus is provided for by the same mechanism of vibratile cilia as in the Asterias.

There are external as well as internal organs of respiration in the Echinoids: the former are the short, pyramidal, branched or pinnate hollow processes, attached by pairs to the oral extremities of the interambulacral areæ, and consequently ten in number: their outer surface is highly vibratile. The internal branchiæ are the transversely extended hollow bases of the tube-feet, which are covered with so rich a network of vessels that Valentin compares them with the lungs the salamander. The chief office of these sacs, according to Tiedemann, is to protrude, by contracting upon their fluid contents, the tube-feet, continued from them through the ambulacral pores; but as the terminal sucker of these feet is unquestionably perforated, Valentin * rejects this explanation: he thinks the tube-feet imbibe the sea-water by their terminal pore, and convey it to the internal basal sac, for the oxygenation of the blood, circulating over its parietes. The sea-water can be admitted into the interior of the visceral cavity through the interspaces of the teeth: if it be actually introduced by the tube-feet it must pass by exosmose through the pores of the basal sacculi, which is contrary to analogy.

The external branchiæ are a more complicated form of respiratory sac everted and extended; they float in the external respiratory medium, while the internal sacs receive it into their interior.

Cuvier, Tiedemann, and Delle Chiaje have given more or less accurate descriptions, but conflicting explanations, of the vascular system of the Echinus. There is no doubt that the fusiform dilated contractile vesicle, situated near the œsophagus, and surrounded by a double fold of the mesentery, is the central organ or heart. Its cavity is subdivided by muscular walls. From its oral end a trunk proceeds, which forms a circle around the œsophagus at the base of the lantern, from which the vessels of that part proceed. A second trunk is continued from the opposite end of the heart, in the opposite direction, and forms a corresponding circle around the anus. A vessel called the intestinal artery runs along the concave margin of the intestine; another trunk called the intestinal vein accompanies the outer or convex contour of the intestine, and receives many branches from the membrane of the shell. The vascular circle round the anus (*fig.* 98, *f*), receiving the veins of the ovaria, sends off five trunks which run in the interspaces of the bases of the tubular feet, or internal branchiæ: the capillaries of these branchiæ return into five other trunks, accompanying the preceding five along the median interspace. One set must fulfil the office of branchial arteries, the other that of branchial veins. The blood is of a deep yellow colour: the blood-cells are granular and irregular but generally manifest a nucleus.

Prof. Valentin, after a minute and searching scrutiny into the anatomy of the vascular system of the Echinus, is unable to deduce from that alone the course of the circulation. The ascertained facts will permit of two explanations. In the first and most probable mode the heart transmits arterial blood to the artery proceeding to the lantern, and from its arterial ring to its soft parts, to the pharynx and to the buccal membrane. From these parts the blood returns into the venous ring of the lantern, and thence into the intestinal vein, where, mingling with the venous blood from the intestine, it is conveyed to the annular vessel of the rectum, which also receives the venous blood of the ovaria. The blood thence passes into the five trunks which represent the branchial arteries. These distribute the blood over the internal gills, or bases of the tube-feet, where it acquires the arterial character. Thus changed, the blood returns by the branchial vein into the arterial ring of the anus, whence it is distributed in part to the ovaria, and the remainder by the intestinal artery to regain the heart. In this view the vessel called by Tiedemann the intestinal artery performs the office of a vein.

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* [illegible]

According to the second explanation, the heart transmits the arterial blood by the intestinal artery to the œsophagus, intestine, and rectum, and then supplies the ovaria, and perhaps also the membrane of the shell. The venous blood collected into the intestinal vein is poured into the anal venous ring, which receives the ovarian veins, and distributes the blood through the five branchial veins: these will disperse it over the branchial sacs, where it will be oxidized. Thus changed, the blood returns by the branchial vessels towards the auricles, and would be continued by their apertures into the vessel of the internal oblique ligament, would then pass along the pharynx, gain the arterial circle of the lantern, and re-enter the heart by the vessel which passes from the lantern to it.

The circular vessel of the chylaqueous system surrounds the gullet at the base of the lantern external to the arterial circle, between it and the nervous ring. With the chylaqueous ring are connected the Polian vesicles and the sand-canal — here a membranous tube. From the circular canal five vessels extend along the ambulacral spaces to supply the system of tube-feet. The chylaqueous has no connection with the proper vascular system.

The nervous system consists in the *Echinidæ*, as in the *Asterias*, chiefly of a delicate chord surrounding the pharynx, immediately external to the chylaqueous ring, and of five trunks extending along the ambulacral interspaces. The pharyngeal ring is an equilateral pentagon in the *Echinus*, and an oblong pentagon in the *Spatangus*. In the Echinus the ambulacral nervous trunks are flattened, and may be distinguished from the vessels by the connection of the latter with the internal branchiæ. Smaller nervous branches are sent off from each arch of the pentagon to the inter-pyramidal muscles and the œsophagus. The ambulacral or branchial nerves diminish in size as they proceed, supplying the internal branchiæ and the ambulacral tube-feet; they finally terminate by penetrating the pore of the ocular plate to gain the base of the red ocellus.

The generative apparatus of the Echinus consists of five membranous sacs (*fig.* 98. *h*, *h*), the efferent ducts of which perforate five plates, surrounding the anal plates, and thence called genital or ovarian plates. This structure is common to both sexes, which are in distinct individuals in the Echinoids, as in the Star-fishes. The ovaria, when distended with the mature ova, which generally present a bright orange colour, fill a great part of the cavity of the shell, and resemble the ovaria or roe of fishes. They have at all periods constituted a favourite article of food with the inhabitants of the Mediterranean shores.

The ova consist of a vitelline membrane, a vitellus, the transparent germinal vesicle, and its solid nucleus.

The spermatic corpuscles are elongated, oval, rounded anteriorly, pointed behind. They abound in the opake milky fluid, distending the five secerning sacculi at the breeding season.

In the multiplicity of the pieces of which the shell of the Echinus is formed, we may discern, by the contrast which it presents with the bivalve and univalve characters of the shells of the Mollusca, the same low vegetative condition of an external skeleton which is exemplified by the frequent repetition of similar parts in the multiplied mouths of the Polypi, the multiplied stomachs of the Polygastria, the multiplied ovaria in the Tæniæ, and the multiplied marsupia in the Medusæ. If we view the articulated moveable spines and the extensile and prehensile tubes in the light of primitive forms of locomotive extremities, we shall see in their great numbers and irrelative repetition an illustration of the same law.

Holothurioidea. The *Holothuria*, which is the highest organised of the Echinoderms, may be compared, as has been already observed, to an Echinus deprived of its spines, with its shell softened and elongated by divarication of its poles. The coriaceous integument is strengthened by scattered areolar calcareous concretions, and continues to be perforated by innumerable apertures, which give passage to tubular feet of precisely the same structure as those in the sea-urchins and star-fishes. These tube-feet are likewise in some species of *Holothuriæ* disposed in five longitudinal ambulacral series; in a few species (*Psolus* Oken) they are confined to a sort of ventral disc: in other species they are generally diffused over the integument. The chief calcareous substances in this coriaceous integument consist of a circle of osseous pieces, usually ten in number, and homologous with the parts of the "lantern" in *Echinus*, which partly defends the nervous ring, and affords a firm attachment to the branched retractile tentacles which surround the mouth. These tentacles may be likened to a more complicated form of the ordinary tube-feet of the body, each being connected at its base with a long hollow sacculus, and being distended and protruded by the injection of the fluid therein contained. In *Synapta* the oral circle includes twelve plates, five of which are perforated for the passage of the chylaqueous canals. The integument in this genus is beset with small anchor-shaped spiculæ, which are articulated to reticulate calcareous plates in the skin.*

The alimentary canal of the Holothuria is closely analogous to that of the Echinus; but its disposition is accommodated to the vermiform character of the softer-skinned species: its anal termination dilates into a cloaca, from which two long ramified cæca are continued; but these admit only sea-water from the cloaca. In the Synapta (*Holothuria digitata*, Montagu) the stomachal portion of the alimentary canal is defined by its strong muscular parietes: there are distinct layers of muscular fibres in certain parts of the mesentery, which also has many peculiar slipper-shaped ciliary organs $\frac{1}{20}$th of a line in length, its general surface not being ciliated.

The alimentary canal in the *Sipunculus*† differs from that in the *Holothuria* in being reflected from the posterior extremity of the body to terminate near the anterior end, without dilating into a cloaca, and without the development of any anal cæca. The intestine is longer and more convoluted in its course. The *Sipunculus* is a marine vermiform animal which burrows in sand, and, although it has no tegumentary tube-feet nor organs of respiration, is most closely allied to the *Holothuria*, and is therefore retained in the class *Echinoderma*, in which it makes the nearest approach to the true Vermes. The oral tentacula are replaced by a kind of proboscis provided with a circular fimbriated lip, and two contractile vesicles appear to be connected with the erection of the fimbriæ. The anterior position of the vent in the *Sipunculus* precludes the necessity of the worm quitting its retreat to evacuate: and its safety seems to demand such a modification on account of its integument being less thick and coriaceous than in the Holothuria.

The rich vascular system of the Holothuria is most conspicuous upon the intestine and mesentery, and has been beautifully illustrated by the injections and drawings of Hunter.‡ Here, however, we find the intestinal vessels carrying the nutrient fluid to those cloacal cæca which are transformed into a distinct respiratory organ, and which presents the form of two long and beautiful arborescent tubes. The complex circulating system in the Holothuria is in great part represented in this diagram (*fig.* 100.) in connection with the equally extensive system of chylaqueous sinuses and canals which regulate the protrusion and retraction of the numerous tubular feet. The most important part of the circulating system is the trunk (*e*), which runs along the free border of the intestine, and which is characterised by the short and wide vessel (divided at *f*, *f*) homologous with the heart in the Echinus, and which connects the corresponding vessels of the two principal folds of the intestine. The intestinal capillaries reunite, performing at the same time the office of absorbents and conveying the chyle to the great intestinal vein (*g*), from which proceed the singular and beautiful respiratory plexuses (*h*, *h*), which are submitted to the influence of the sea water by contact with the branchial trees (*n*, *n*). The aerated blood is conveyed to a great mesenteric trunk (*i*, *i*), or branchial vein, from

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* CLXVIII. Heft. ii. p. 12. CLXIX. p. 35.

† Prep. No. 438. A.

‡ See Preps. Nos. 437, 438. 984., and X. pls. 3. and 49.

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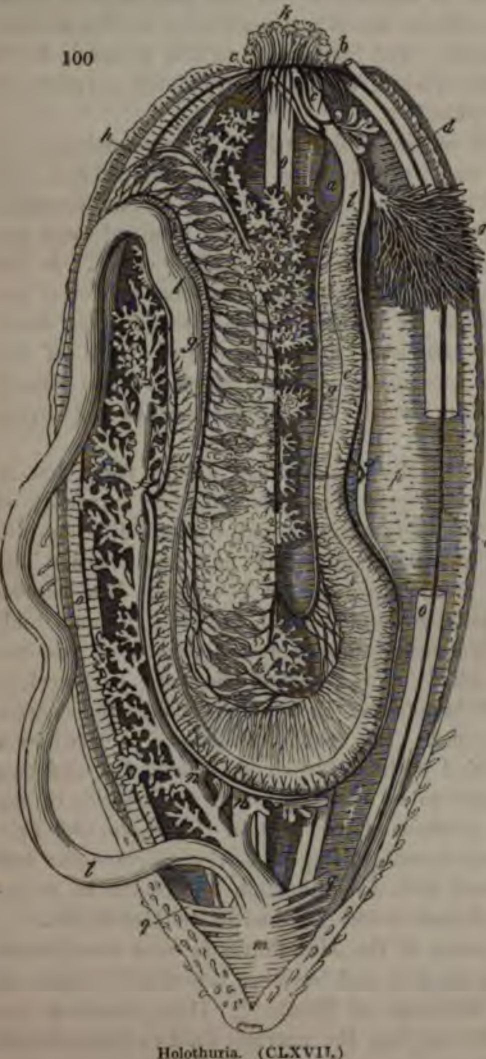

Holothuria. (CLXVII.)

which it is transmitted to the parietes of the body, and returns by the cloaca to form the intestinal artery.

The ampulla Poliana (*fig.* 100. *a*), which is double in some species, is the homologue of the blind sacculi, which supply the circular chylaqueous canal sending off the vessels to the bases of the feet in the Asterias. It transmits its fluid principally to an annular reservoir round the pharynx (*b*), whence proceed the canals of the oral tentacula (*c*) and those supplying the tubular tentacles or feet which perforate the coriaceous integument. The latter canals (*d*, *d*) run down in the interspaces of the pairs of muscles, and distribute transverse branches to the bases of the tubes as they proceed.

Hunter * has figured certain glandular sacs opening into the stem of the hollow branchiæ (*n*, *n*), which may be regarded as a rudimental form of an excretory or renal system.

The chief divisions of the nervous system consist of the pharyngeal ring, which is closely applied against the inner side of the circle of calcareous plates, and of the flattened chords which proceed, external to the chylaqueous canals, along the groove or middle interspace in each of the pairs of longitudinal muscles. These muscles are attached anteriorly to the calcareous plates, are arranged in five pairs in most Holothuriæ, and traverse the interior of the integument of the animal through its entire length. The integument is also acted upon by transverse fibres which run external to the longitudinal bands; and such is the irritability of this muscular system, that when the Holothuria is disturbed or captured it will sometimes eject its sand-laden intestine and most of the other viscera by the clöacal aperture, and very effectually unfit itself for anatomical investigations. The longitudinal muscular bands are more numerous in the Sipunculus, and the stratum of circular fibres is more distinctly developed. The disposition of the nervous system accompanies this progress towards the annulose type, and only a single ventral chord is sent off from the pharyngeal collar.†

The generative organs of the Holothuriæ constitute, as in other Echinoderms, a very considerable part of the abdominal viscera in the breeding season; but they present a more complicated form: they consist of a branched system of long and slender cæcal tubes (*fig.* 100. *r*), opening externally by a single common canal, whose orifice is near the mouth. The generative organ of the male Holothuria resembles that of the female in structure; but the sexes may be readily recognised at the breeding season by the different character of the contents of the tubes, which are white or colourless in the male, whilst the ova present a reddish or yellowish hue.

* X. Vol. i. pl. 3.

† Prep. No. 1292.

The generative organs of the Sipunculus are two straight, slender, unbranched, blind tubes, symmetrically disposed, and terminating each by a distinct orifice at the anterior third of the body.

With respect to the generation of the Echinodermata there seems to be no instances of the mode by gemmation, and very few of that by spontaneous fission. This, however, has been noticed by Montagu in the *Holothuria* (*Synapta*) *digitata*, which separates itself without violence into an indefinite number of pieces, apparently by muscular constriction; and he deems it probable that it thus multiplies itself by natural division. He discovered this Echinoderm on the coast of Devonshire.* In another species of *Synapta* (*S. Duvernœa*) M. Quatrefages states, that it, also, is in the habit of casting off segments from the extremity of the body, and that the segments so cast off begin to move, and ultimately acquire the form of the parent animal.† Professor Müller has observed that, in *Synapta digitata*, the head once separated, the fragments of the body, however long they may be, do not break up again, but remain living and moving for a day or more: but the piece with the head redivides as often as it is irritated, and it is only by longitudinally bisecting the head that this process can be finally stopped.‡ Whoever has examined the Holothuriæ in a state of nature must have been struck with their proneness to spontaneously eject the interior organs: Sir J. G. Dalyell, after witnessing this phenomenon, found that they had the power of reproducing the alimentary canal, and he observed another process, in which the parts of the entire body were separated by spontaneous fission.§ The brittle-stars (*Ophiocoma*) are remarkable for the promptness with which they break themselves up into pieces when laid hold of; and equally so for the power they possess of reproducing their arms. If a portion of the disc remain attached to a separated arm, the entire individual may be reproduced. But this is an exceptional mode of increase in the Echinoderms.

The ordinary mode is by the formation of ova and sperm, followed by impregnation. As a general rule, these reproductive elements are respectively developed in distinct individuals. But the genus *Synapta* offers an exception: here the organs of generation are yellow bands suspended from the pharynx and floating freely in the abdominal cavity, where they exhibit vermicular movements. They are covered with a ciliated epithelium: the thick walls of their cavity consist externally of a muscular layer, next of a glandular layer in which the sperm-cells and spermatozoa are developed, and the innermost layer has a cellulo-glandular structure in which the ova are developed; and thus is arranged the combination of male with female parts, which we shall find not uncommon in the hermaphrodite mollusks. In all other known Echinoderms, the male organs are peculiar to one individual, and the female organs to another; but the organs are very much alike in both sexes, and, with the modifications which have already been described, are, upon the whole, simple in their structure.

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* CLXXX. p. 22. † CLXIX. p. 60. ‡ CLXX. p. 24. § CIX. vol. ii.

With regard to the development of the typical star-fishes, we are indebted for our first and chief information to Sars.* This conscientious observer found, in the month of March, great numbers of a small kind of star-fish crouching under the rocks at low water, of different forms, but generally with their disc forming a prominent dome above them. The ova, as they become matured in this species, assume a comparatively large size, break out of the ovisacs, and escape by the genital apertures near the mouth. The ova are of a bright red colour, and are received and incubated, as it were, in the hollow of the dome-shaped disc; and in them Sars traced almost every stage in the development of the species. He commenced his observations in the month of February, 1840, at Floröe, in Norway, on the species called *Echinaster sanguinolentus.* This has ten ovaria, usually whitish, then reddish, as the ova are matured. In these the chorion is strong and elastic, the yolk finely granular; there is no white or albumen. The nucleated germinal vesicle is large and distinct, and usually escapes entire when the egg is burst under compression. The ovaria are grape-like bunches of pyriform sacs, with ova of different sizes: they being progressively developed. In each ovarium two or three eggs were as large as all the rest put together. The thin, colourless chorion immediately invests the yolk, which is blood-red and opaque in the big eggs: in the small ones it is lighter coloured and clear, permitting the germinal vesicle and nucleus to be seen. In March he found seven or eight large eggs in each ovarium.

How they escape was not seen; the genital pores were too small to be clearly discerned. Tiedemann thinks the eggs escape by the pores above the five dentated processes of the mouth, and Sars thinks so likewise; because he once, by pressure on the body of the star-fish, saw a red slimy filament, like the yolk of squashed eggs, come out of a little hole near the angle of each ray, above the mouth, and because the ripe eggs are always at the upper or free end of the ovarium, and not likely to traverse the stem or radius of the oviduct which he deems a tendinous band. Most likely they fall into the cavity of the body, and so reach the genital pores on the ventral surface. The *Echinaster* cannot have these pores on the dorsal surface (as Müller describes in the *Asteracanthion rubens* and *Solaster papposus*), because the ova would fall into the sea, and not into the ventral concavity, into which they are received, as into a marsupium, and are hatched there. On the 17th March, Sars found the star-fish strongly contracted, and the disc raised into a dome shape, the mouth and its surrounding parts forming the pouch, in which the ova are hatched, and the young remain some time. Some embryos were one and a half line, others three-fourths of a line, in size: the ova and the monadiform young are loose in the concavity; but the further developed young are attached by a special pedicle to the walls of this improvised marsupium.

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* CLXIV. and CLI. p. 47., pl. 8.

The impregnated eggs have the chorion separated from the yolk or germ-mass by a clear fluid. In the excluded ova the germinal vesicle had disappeared, and the yolk was seen in different stages of division. On the 7th March, at 9 a.m., the yolk was seen in two hemispherical, not quite distinct parts. In the evening each of these were similarly divided, forming four lobes. At ten the next morning, each lobe had again divided, and thus eight spheroids were seen. In the evening of the 8th all the surface of the germ-mass resembled a mulberry. On the 17th March the ciliated embryos were seen, oval, blood-red, swimming about the marsupial chamber. They first develop two tubercles, then four tubercles, which are ciliated, and they swim, rotifer-like, with these forwards. Afterwards the body becomes depressed. The next, which may be called the pentacrinal or polype, stage, was noticed on the 3rd April, when the embryo star-fishes presented an organ of adhesion or pedicle, well developed; it is short, cylindrical, with thick round ends; four shorter processes then bud out, and a fifth much smaller tubercle.

The smooth dorsal surface, and the ventral surface of the flattened body, may be now recognised, with five double rows of small, clear tubercles, radiating from the centre: these become the ambulacral tentacles. The young attach themselves, like crinoids, by their quadrifid pedicle to the side of the glass vessel into which they may be put. When detached, they still can swim round the bottom of the glass by the cilia covering the pedicle and body, with the pedicle foremost, and the belly upwards. When turned with the back upwards they lay still. The whole yolk is here converted into the germ-mass, and then into the embryo.

On the 15th April, five corners began to grow out of the periphery of the depressed body. Ambulacral tentacles protrude from the tubercles. At the under surface and outer end of each of the arms or rays one sees a small, round tubercle, which is persistent, and, from its constancy and early manifestation, important: it becomes the so-called eye. The back is now convex, and raised clear from the arms. The quadrifid attaching pedicle still remains in the interspace between two of the arms, more towards the ventral than the dorsal surface.

On the 23rd of April the five arms were very distinct, the ambulacral tentacles were longer, and now the young creeps by means of them, and alters its position when turned on its back. The attaching pedicle contracts, and becomes softer and more contractile. On May the 1st it was reduced to two tubercles, and was more on the dorsal side, at the angle between the two arms; and the hitherto bilateral asteroid now becomes the completely radiated animal; the five arms lengthen, their small spines grow, the ciliograde powers are lost, and the young star-fishes creep away, and slowly acquire the mature dimensions.

In the larva of another species of star-fish, to which larva Müller * gave the name of *Bipinnaria*, the long oblique fissure lodging the mouth is bordered by a ciliated fringe, and there is a distinct circular band of cilia above, and in front of the oral fissure, the anterior boundary of which is formed by the hind part of that band. The intestine is short and straight. The anus opens on the ventral surface of the body. The *Bipinnaria* grows to the length of an inch or more, chiefly by the increase of the anterior part of the body, long processes being developed from the ciliated fringe and band, which form two fin-like expansions one above the other.

The next series of metamorphoses which claim our attention are those which Müller has traced out in the genus *Ophiura*. In 1835, this eminent physiologist and naturalist visited the coast at Heligoland, accompanied by some of his pupils, and they occupied themselves in investigating the minute forms of marine animal life. They met with some singular forms, and the results of their researches were communicated to the Academy of Sciences at Berlin.† Three minute animals, about 1·4 or 1-2 line in diameter, were referred respectively to the genera *Mesotrocha*, *Vexillaria*, and *Pluteus*. The first of these afterwards proved to be the larva of a Nereis, the second of an Ascidian, and the third of the Echinoderm in question.

The *Pluteus* is compared, in form, to an easel; it is better adapted than the larvæ of the *Asterias* for observation, because it is more transparent. It resembles the larvæ of the ordinary star-fishes in having an elongated form, traversed by a straight intestine with the mouth at one extremity and the anus near the other, and in being girt by a ciliated fringe; but the fringe passes above the mouth and before the anus, completely encircling the body obliquely, and is continued upon the processes, all of which are developed in one direction, in which they are divergent, and the creature is more plainly bilateral; the processes are also longer, and have no relation to fixation. The body is conical and pointed behind, and branches into eight processes in front; these contain calcareous rods and spiculæ, which also occur, interlacing, on the upper part of the body; the lateral processes are the longest, and each process is provided with two ciliated borders, which are prolongations or continuations of the encircling fringe. The obtuse points of the body, and the ends of the processes, are orange-coloured: the other parts are colourless and transparent. These *Plutei* occur in great numbers in August and September, when they are from one to two lines long: they swim freely, with the processes turned forwards. One part of their truncated side is prolonged into a single flat and wide process, which carries the mouth and gullet: on the side of the hemispheric portion opposite to this is the circular anus. The mouth and stomach are ciliated. A little contractile movement of mouth and pharynx may be noticed; but the streams of nutriment are seen, by means of indigo, to be directed by ciliary action towards the mouth. Two small ganglions are situated below the mouth, from which nerve-filaments diverge. These larvæ are not luminous by night.

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* CLXXIII. p. 29. taf. vii., fig. 5—8.

† CLXXI.

The first indication of the production of an *Ophiura*, within the *Pluteus*, is the appearance at the sides of the stomach and pharynx, or the granular germ-mass, of certain cæcal winding tubes, with a double contour: they soon surround the so-called stomach like a circle; they next project from the surface, like tubercles; then the whole takes on the form of a disc, with five short processes. The embryonal ciliated arms, or rods, take no share in the formation of this disc. Calcareous spiculæ begin to take a new arrangement on the incipient disc and arms. The mouth of the *Ophiura* is a new formation: it is at first round, and quite distinct from that of the *Pluteus*, which disappears. Before the processes of the *Pluteus* disappear, the tentacula of the arms of the *Ophiura* are developed. Short processes or plumes next shoot out on each side the base of the elongating rays or arms, and these processes move violently. The remnant, or case, of the ciliograde *Pluteus* is absorbed or cast off, and the young *Ophiura* is plainly manifested. The transparent gelatinous larval animal, from its general resemblance to the *Beroïdæ*, might be classed with the ciliograde acalephs, but for the appearance of certain opaque lines of calcareous matter.

In regard to the next order, the *Echinoidea*, the observations of Prof. Müller are more full and remarkable. His attention was attracted by the circumstance of some of the minute *Plutei* differing from others in certain proportions, in having three processes with calcareous rods developed from the hinder convexity of the larva, and by the development of particular tubercles, richly beset with cilia.

V. Baer, who led the way in experimenting and observing the artificially impregnated eggs of the Sea-urchins (*Echinus*), found them to be first developed into a ciliated monadiform animalcule, like that of the *Medusa aurita.* In the course of four days this had become metamorphosed into a minute transparent acalephoid creature which he compares to a Beroë. Here his observations ceased, the animals having perished on the fifth day.

In the autumn of 1845 Professor Müller discovered in the sea at Heligoland the transparent acalephoid animalcules which have been mentioned, referable by this mode of motion to the "ciliograde" order, one of which, from its singular form, somewhat resembling a painter's easel, he described under the name of *Pluteus paradoxus.* Returning in the following year to the same field of observation, he pursued with admirable detail the change of this species, as above described, into an *Ophiura* (Brittle star-fish), and that of the other kind of *Pluteus* into an *Echinus.*

The larva of the *Echinus,* like that of the *Ophiura,* has a quadrilateral pyramidal body, of a colourless, transparent, or hyaline substance, dome-shaped behind, expanded and slightly excavated in front, the corners of which are prolonged into straight slender legs, strengthened by filiform rods of calcareous matter, reaching to the summit of the dome: the mouth is prolonged from the middle of the concave base into a four-sided proboscis, the angles of which are also produced into slender processes shorter than the four outer legs. Were the creature to stand upon these it would resemble a table-clock case, and the proboscidiform mouth and appendages might swing to and fro like the pendulum. The larva is, however, a free-swimming animalcule, and propels itself, with the base and processes forwards, chiefly by means of strong cilia, grouped on two tubercles at the sides of the dome, which are compared to epaulets: but it is also provided with a fringe of cilia, girting the dome and continued upon all the columns, up one side and down the other. The mouth is surrounded by a distinct band of cilia: it is triangular and bounded inferiorly by an oblique projecting lip. In the centre of the dome-shaped body is a subspherical granular mass, apparently the remnant of the primordial germ-mass, which Professor Müller calls the stomach, and which doubtless surrounds the cavity to which the mouth and pharynx conduct.

The first evidence of the change to the *Echinus* is the formation of a circular disc, like a clock-face, on one side of the granular mass: five double lines, like pointers, radiate from the centre of this disc, and their extremities expand into circles with a double outline. These circles form the bases of as many hollow tentacles, like those that traverse the ambulacral pores of the adult *Echinus*, but which are here single, not in pairs. Opposite this disc there appear upon the dome, on each side, two triradiate pedicellaria, which exhibit spontaneous motion, the arms of the pincers opening and shutting. The disc progressively expands, extending over the cellular mass to which it owes its origin, and developes tubercles, which push through the transparent dome of the *Pluteus*, and are transformed into spines and tentacles, both of which, together with the pedicellariæ, manifest their characteristic motions and combine these seemingly voluntary actions with the automatic continued vibrations of the ciliated epaulets of the larva; so that it can now both swim and creep: the mouth of the larva still remains in its first position and, like the œsophagus, is in full action. By the time the disc has grown over half the granular sphere little of the larva remains, except some of the slender calcareous rods, and the mouth is obliterated: the perforated oviducal plates are formed round the pentagonal space, as yet imperforate, in the centre of the original disc, determining the anal pole of the developing spiny globe, close to which the cicatrix of the ruptured pharynx of the Pluteus is completed by the so-called "madreporiform plate." The mouth of the *Echinus* is quite distinct and remote from that of the *Pluteus*: it is first indicated in the centre of the naked or unspined moiety of the granular sphere by the formation of the hard summits of the five characteristic dental masses of the *Echinus*. The spines, which soon acquire a considerable length, contain a calcareous framework. When the latter is perfectly developed, it forms a hexagonal prism placed within the cylindrical skin of the spine, which consists of a regular calcareous lattice-work, terminating at the extremity in minute teeth. The horizontal arrangement of the solid network of the spine is radiate. Before the framework of the spine is thus far developed, when it first appears, it has exactly the form of a candelabrum. The basis of the framework of the spine is then a star with six rays, from the centre of which there arises a single axis, which immediately subdivides into other branches which subsequently re-unite. The segments of the delicate nascent shell of the Echinus growing into tentacles and spines cannot be considered as the subsequent plates of the shell, but as the foundations of the tentacles and spines. The outer skeleton is at length completed by the [illegible] extension of the "ambulacral" and "interambulacral," [illegible] plates, and by the less regular "oral" plates.

Thus the *Echinus* is completed, and becomes either a male by the development of testes, or a female by that of ovaria. The ova are impregnated, and develope the monadiform embryo: this is probably metamorphosed into the beroiform *Pluteus*, which produces, by "metagenesis," rather than by "metamorphosis," the young *Echinus*, which completes the cycle by growing into the oviparous adult.*

In so defining the nature of this process in the work above cited, I wished to express the fact, subsequently recognised by an able commentator on Müller's original and admirable observations†, viz., that the new or echinoid structure throws off a large part of the pluteal larva in and from which it was developed.

In the metamorphoses of the *Holothuriæ* the nascent mature form unites with the larval one, no part of the latter being thrown off. The larva of the *Holothuriæ* is bean-shaped, convex dorsad, concave ventrad. An irregular transverse fissure answers to the hilum of the bean, and in this the mouth is placed. The margins of the fissure are edged by a ciliated fringe exactly similar to that of the *Pluteus*. The anus opens on the ventral surface of the larva, behind the fringe, which forms a continuous circle, the anterior part of which is bent back to form the anterior margin of the fissure in which the mouth lies. In the course of its growth the margins of the larva and the corresponding parts of the fringe are thrown into numerous lateral processes, which give it a scolloped appearance. A portion of the dorsal integument of the larva is inverted towards the stomach, as a tube terminated by an enlarged globular extremity, whose cavity communicates with the exterior and is ciliated internally. The vesicle, which terminates this tube, now sends forth processes, forming a "rosette," which lies close upon the stomach. The rosette becomes the circular canal of the chylaqueous system, from which cæca are given off anteriorly to form the tentacles, posteriorly to form the chylaqueous canals. The former mouth of the larva is obliterated, and a new and permanent one is formed in the centre of the circular canal and its tentacular appendages. In the meanwhile the Polian vesicles are developed from the circular canal, and a deposit of calcareous matter takes place round a portion of the tubular canal, from whose globular extremity the chylaqueous system has been formed. That portion of the tubular canal which lies between the dorsal parietes and the calcareous deposit dies away, and the remainder hangs freely from the circular canal as the "sand canal."

The rose-coloured ova of the *Sipunculus nudus* are found in vast numbers in the breeding season floating in the chylaqueous fluid of the abdominal cavity. The males show in the same fluid a like abundance of subdepressed roundish heaps of aggregated vesicles or cells full of granular matter. These are the formative cells of the spermatozoa: they continue in this undeveloped state all the winter, but in the early spring the surface of the granular masses begins to be beset with minute filaments, and in the middle of April the liberated spermatozoa abound in the chylaqueous fluid.

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* XXX. p. 22.

† CLXXVII. p. 9.

The chorion of the mature ova is uneven, and its surface is beset with oblong nucleated cells: the yolk is inclosed by a firm membrana vitelli, with a facetted surface, like the cornea of insects: it is divided by some limpid fluid from the chorion. The yolk is minutely granular, and contains a clear germinal vesicle with a solid nucleus. The embryo, when developed, carries out with it part of the peculiarly facetted vitelline membrane, of which it afterwards disembarrasses itself. The broad semicircular head of the larva supports a pair of pigment- or eye-specks, behind which it is encircled by a ciliated band. The alimentary canal floats in an abdominal cavity: the pharynx is divided by a constriction from the capacious stomach: a short and narrow intestine is twice bent, its last fold returning to terminate on the dorsal surface of the body, and thus early indicating the characteristic position of the vent in the adult. The two blind sacs are short and wide, and open on the sides of the ventral surface of the abdomen. There is a pair of small spherical glands beneath the pharynx, with a common duct which opens just in advance of the ciliated band. A pair of retractor muscles proceed from both the dorsal and ventral aspects, to be inserted into the band for its retraction, and five or six more feebly developed transverse bands for the constriction and elongation of the body may be discerned.*

Thus it appears that, diversified as are the mature forms of the Echinodermata, each begins its free and locomotive existence as an oval ciliated larva, like a polygastric animalcule: the variations in the subsequent metamorphoses are thus summed up by Professor Müller:—

"1.—The change of the bilateral larva into the Echinoderm takes place when the larva yet remains an embryo, and is wholly covered by cilia, without a ciliated fringe. A part of the body of the larva takes on the form of the echinoderm: the rest is absorbed by the latter. (A part of the *Stelleridæ*, e. g., *Echinaster*, *Asteracanthion.*)

"2.—The change of the bilateral larva into the Echinoderm takes place when the larva is perfectly organised; that is, possesses digestive organs and a ciliated fringe. The Echinoderm is constructed within the Pluteus, like a picture upon its canvas, or a piece of embroidery in its frame, and then takes up into itself the digestive organs of the larva. Hereupon the rest of the larva disappears (*Ophiura*, *Echinus*), or is thrown off (*Bipinnaria*).

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* CLXVIII.

"3.—The larva changes twice. The first time it passes out of the bilateral type with the lateral ciliated fringe into the radial type, and receives, instead of the previous ciliated fringe, new locomotive larval organs, the ciliated rings. Out of this pupa condition the echinoderm is developed without any part being cast off. (*Holothuria* and some *Stelleridæ*)." *

Prof. Müller, whilst prosecuting his researches into the development of the soft vermiform species of *Echinodermata*, at Trieste, in August, 1851, was further rewarded by the discovery of a very singular phenomenon. In upwards of seventy instances he found in the *Synapta digitata* a tube, one half green, the other half yellow, and in more than twenty instances this tube was organically connected by both ends with the Synapta, — viz. to the head by its yellow half, where the tube opens externally, and to the intestine by its green half, which contains an intus-suscepted portion like the inverted finger of a glove. The vessel which runs along the free side of the intestine gives off a branch which surrounds the open end of the intus-susception. Where the sac is embraced by the vessel it is enlarged into a sort of knob, from the middle of which the involuted portion passes into the interior of the sac. The place of attachment is a short way behind the muscular stomach. Sometimes there are two or three such tubes so attached one behind the other: their outer surface is not ciliated, like the ordinary branched ovarian tubes of the Synapta: they exhibit slow vermicular motions executed by a muscular coat consisting of transverse and longitudinal fibres; the inner surface, save at the green portion, presents a lively ciliary motion, and in this ciliated part the sperm-sacs and ovarium lie free. The ovarium is a closed tubular capsule, ciliated upon its whole outer surface: it contains orange-coloured ova, attached to short branches from a central stem: each ovum consists of a yolk, and a germinal vesicle $\frac{1}{30}$th of a line in diameter : when fully developed the ovarian tubule is rent, and the ova escape into the common tube. The sperm sacs are from eight to eighteen in number, and lie free in a rather wide portion of the common tube: they are lined by a layer of cells, and are filled with Spermatozoa. These are liberated by solution of their formative sacs, and impregnate the similarly free ova. The progressive geometric fission of the yolk follows: a ciliated embryo is developed, which afterwards acquires a shell, about $\frac{1}{10}$th of a line in diameter, and effervescing with acids: a discoid foot, like that of a gastropod, is formed, which supports an operculum; and a respiratory cavity is established like that of a Pectinibranchian: in short, an unmistakeable young univalve mollusk is the result of the development of the impregnated ova in the tubular sac—hence called "molluskigerous"—which Prof. Müller discovered in so many specimens of the *Synapta*.

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* CLXXIV. p. 33.

In two cases the molluskigerous sac was found in specimens which also possessed the ordinary generative organs of the *Synapta*, and this coincidence might have been more common had not the specimens brought for examination consisted only of those fragments of the body which result from the usual spontaneous transverse fission which follows the capture of this Holothurioid. The shell of the embryo so developed bears most resemblance to that of the *Natica*, and it remains to be determined, therefore, how the Mediterranean species of that genus propagate and are developed.

The analogies that offer the most probable explanation of the occurrence of a molluskigerous sac in an Echinoderm also possessing the ordinary generative organs of its class, are such instances of parasitism, for the purposes of development, as occur in the lymneus infested by the cercarial larvæ of a distoma, in the bee which hatches the strepsipterous larvæ, and in the living caterpillar which is made the similar nursery of the ichneumons.

We have here, therefore, probably a generic phenomenon, which relates more immediately to the *Gasteropoda* than to the *Echinodermata*, and I shall return to the latter with a few concluding words on the singular metamorphosis of the *Comatulæ*. The ovicapsules of this genus, which are developed in each of the pinnæ of the long and branched rays, at least as far as the fifteenth or twentieth pair, become distended with ova about the month of July, when they escape by a round aperture, but adhere together for a while, in a cluster of about one hundred. They have been next observed dispersed, and attached in the form of flattened oval discs to corallines and sea weed; they then develope an obscurely jointed stem, ending in a clavate head, which soon shows traces of the arms and mouth with its tentacula. When the column presents a distinct division into twenty-four joints, its expanded capital bears five bifurcating arms, which are at first simple, but afterwards acquire the pinnæ, and subsequently the dorsal cirri. They further resemble small Comatulæ, in having a median mouth and a distinct lateral prominent vent, as well as in their sulphur-coloured arms. These small Pentacrines attain the height of about three-fourths of an inch, and were originally described by their discoverer*, to whom also we owe the subsequently acquired knowledge of their metamorphoses, as a new species of *Pentacrinus* (*P. Europæus*). These small Pentacrines entirely disappear in September, at which season the young Comatulæ make their appearance: but the actual metamorphosis of the Pentacrine into the Comatule has not yet been seen. The latter we know enters life as an active ciliated larva; it next selects a suitable situation for its sedentary pentacrinite stage of existence; and analogy plainly indicates that the crinoid capital, dropping from the stalk by an act of transverse fission, becomes the Comatula, which thus a second time assumes a free condition of existence under its mature form. Nor are these metamorphoses a whit more extraordinary than those of the gelatinous Medusæ: nay, the parallel would be extremly close, since we saw that the Cyanæa entered life as a ciliated locomotive infusory, then became a sedentary polype, supported on a central stem, which finally resolved itself into freely swimming aclephans by several transverse fissions. Other highly interesting considerations arise out of the predominance of the Crinoid forms over the Asteroids, and of the Cystideoids over the Echinoids in the secondary and palæozoic formations respectively; for the Crinoids would seem to be not the only representatives of the larvæ of actual species, if the bold conjecture of Prof. Ed. Forbes be true, that the pectinated rhombs of the more ancient Cystideæ answer to the ciliated "epaulettes" of the *Pluteus*†: for in that case the pedunculated Cystideæ would, as old permanent forms of Echinus-larvæ, represent the Crinoids in the family Echinidæ.

As we advance in our survey of the organization and metamorphoses of animals, we shall meet with many examples, in which the embryonic forms and conditions of structure of existing species have at former periods been persistent and common, and represented by mature and procreative species, sometimes upon a gigantic scale.‡

Summary of the Orders and Families of the

Class ECHINODERMATA.

Marine, commonly free, repent animals, with the integument, in most, perforated by erectile tubular tentacles, hardened by a reticulate deposit of calcareous salts, and, in many, armed with spines. A vas-system distinct from the chylaqueous and digestive systems; atter in a distinct abdominal cavity; in some a distinct respi- ry organ.

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* CLVIII.

† CLXXIX. vol. ii. p. 184.

‡ LXXXIV. (1843), p. 129. V. Baer rightly characterised the course of development of an individual animal as "a passage from a more general to a more special type." But, in substituting this mode of expressing the idea broached in the text, the modifier of the phraseology seems scarcely justified in claiming that idea as "particularly his own." See IV. (1851), p. viii.

Order CRINOIDEA.

y with ramified rays, supported temporarily or permanently on ed calcareous stem. Alimentary canal with mouth and vent. al organs very numerous and distinct.

Family *ENCRINIDÆ*. Body persistent on stem.
Genera *Encrinus*, *Pentacrinus* (most of the species are extinct).
COMATULIDÆ. Body liberated from stem in the adults.
Genera *Comatula*.

Order ASTEROIDEA (Star-fishes).

ly radiate; integument hardened by calcareous pieces, and or less armed with spines. No dental apparatus. Alimentary canal symmetrical, and in some without a vent.

Family *OPHIURIDÆ*. Genera, *Astrophyton*, *Ophionyx*, *Ophiothryx*, *Ophiomastyx*, *Ophiocoma*, *Ophiolepis*, *Ophioderma*.
STELLERIDÆ. Genera, *Luidia*, *Astropecten*, *Ctenodiscus*, *Archaster*, *Stellaster*, *Astrogonium*, *Oreaster*, *Pteraster*, *Asteriscus*, *Culcita*, *Ophidiaster*, *Chætaster*, *Solaster*, *Echinaster*, *Asteracanthion*.

Order CYSTOIDEA.

Body spheroid, incased in a crust of inflexibly joined calcareous pieces; and supported on a jointed stem.

(All the species are extinct.)

Order ECHINOIDEA (Urchins).

Body spheroid or discoid, incased in a crust of inflexibly joined calcareous plates, and armed with spines. Dental system complex, forming a part called 'lantern.' Intestine convoluted, with a distinct vent.

Family *CLYPEASTERIDÆ*. Genera *Clypeaster*, *Scutella*, *Encope*, *Rotula*, *Lobophora*, *Echinocyamus*, *Mellita*, *Echinanthus*.
ECHINIDÆ. Genera *Echinus*, *Cidaris*.
SPATANGIDÆ. Genus *Spatangus*.

Order HOLOTHURIOIDEA (Sea-cucumbers).

Body vermiform; integument flexible, with scattered reticulate calcareous corpuscles, and a rudimental "lantern." Intestinal canal convoluted, vent terminal. Respiratory organ, an anal ramified tube.

Family *HOLOTHURIDÆ.* Genera *Holothuria, Pentactes, Bohadschia, Cladolabes.*
SYNAPTIDÆ. Genera *Synapta, Chirodota.*

Order SIPUNCULOIDEA.

Body vermiform; integument without calcareous corpuscles, and not perforated by tubular tentacles. Intestinal canal convoluted, vent at the fore part of the body. No respiratory organ.

Family *SIPUNCULIDÆ.* Genera *Sipunculus, Phascolosoma.*
ECHIURIDÆ. Genera *Echiurus, Thalassema.*

LECTURE XI.

ANNULATA.

IN both the infusorial and entozoic classes the body assumes a more perfect linear and bilateral form as the species advance in the scale of organisation; and we have seen in the subjects of the preceding discourse, that even the typical radiated class of the zoophytic province conducts by the holothurian and sipuncular families to the vermiform class of the articulated province, in which the vegetative principle of development, by the frequent repetition of similar parts, is still conspicuously manifested, but exercises its energies in a linear direction, and forms successive segments from before backwards. We find, in fact, at the lowest step of the great homogangliate series of the Animal Kingdom an extensive group of vermiform animals, some of which very closely resemble the trematode, and others the nematoid, Entozoa, and all are devoid of jointed limbs: but they possess a distinct circulating system of arteries and veins, and in almost all the species the blood is red.* They have therefore been

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* The first notice of this colour of the blood in an anellid I believe to be due to Pallas: —

"Ibi trans cutem distincte apparet stria albicans — quam *vena* æqualis, *rubra*, maximam partem sinisterior comitatur."

"Intestino primo longitudinaliter exterius adnascitur ductus crassus, subflexuosus, called "red-blooded worms," "vers à sang rouge," and "anellides," by the French naturalists; in Latin *Annulata*, from *annulus*, a little ring, because the entire body of these worms is made up of a succession of segments like little rings.

The mind is not easily liberated from the sway of opinions that have long been held as authoritative: although Cuvier recognised the exaggerated importance of the zoological character derived by Aristotle from the colour of the blood, yet the judgment of the great modern reformer of zoology continued to be so far biassed by that character, that, in his latest edition of the "Règne Animal," he continued to place the anellids, on account of the colour of their circulating fluid, at the head of the articulate series, above the crustaceans, above the arachnidans, and above the insects, whose transitory larval condition these apodal worms seem permanently to represent.

The body of an anellid is always long, soft, and subdivided into a number of segments, for the most part closely resembling or identical with each other. In many species the first segment is so slightly modified as scarcely to deserve the name of head; in others it is the seat of higher senses and more varied functions, and is at once recognisable as the cephalic segment.

In the lowest forms of the *Annulata* the locomotive instruments are suctorial discs, and the alimentary canal adheres to the integument, as in the Trematode worms; but the suckers are always two in number, and are terminal in position. The species next in order have the alimentary canal less extensively attached, and have stiff hairs or minute hooks projecting from each segment. In the higher Anellides the alimentary canal is freely suspended in an abdominal cavity, and most of the species have on each side of the body a long row of tufts of bristles, supported upon fleshy tubercles, which indicate the rudiments of lateral and symmetrical locomotive members (*fig.* 101.) There are often two such organs, placed one (*a*) above the other (*b*), on each side of the segments of the body. In some species the two setigerous tubercles are confluent,

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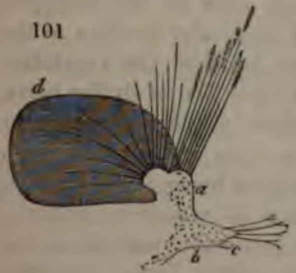

Aphrodita.

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ruberrimo liquore plenus, qui mihi cordis sui trunci systematis vasculosi vice fungi videtur."

"*Vas rubrum* intestinalem tractum concomitans in hac Nereide (*N. conchilega*) æque ac *cylindraria* inveni."

Anatome Nereidis Belgicæ, in "Miscellanea Zoologica," v. pp. 128, 129. (1766.)

and in almost all there exists at the base of each a long soft cylindrical appendage (*c*). The bristles in the setigerous anellids are their chief organs of locomotion, and at the same time their weapons of attack and defence. They are generally sharp, or barbed, and hard enough to readily penetrate the soft bodies which they strike.

The nervous system of the anellids presents a marked advance beyond its condition in the white-blooded parasitic worms; it consists of a double median central chord or chain of small ganglions, extending from one end of the body to the other; the two chords diverge anteriorly to allow the passage of the œsophagus, and again unite above that tube to form a distinct, though small, bilobed cephalic ganglion or "brain."

Most of the anellids are provided with pigment- or eye-specks, "ocelli;" and in many of them the head supports soft cylindrical tentacles, which are obviously organs of touch, but differ from the antennæ of insects in the absence of joints. In the first appearance of these not yet well understood organs of sensation, which form so remarkable and conspicuous a character and so important an endowment of the higher articulate classes, we have again an interesting illustration of the principle of vegetative repetition; for every setigerous tubercle in the anellids with cephalic feelers has a similar organ of sensation: the distinction is merely local and nominal; the feelers on the first segment being called "antennæ;" those on the other segments "cirri."

The mouth is at the lower surface of the head, or at the anterior extremity of the body in the acephalous anellids; in some species it is provided with a protractile proboscis and with lateral jaws in the form of curved dentated horny plates: the alimentary canal is generally straight; in some species simple, in others sacculated, or provided with a greater or less number of lateral cæcums: the anus is situated above, or at, the posterior extremity of the body.

The degree of redness of the circulating fluid varies considerably; in some species it is very pale; in one or two the fluid even presents a greenish hue: it circulates in a closed and very complicated system of vessels, of which the chief dorsal one is distinguished by its undulatory pulsations; and in some species the circulation is further aided by contractile sinuses, called hearts.

All anellids have organs of respiration, adapted in a few species for extracting oxygen directly from the atmosphere, and in the rest of the class through the medium of water: in these the gills are usually external, vary considerably in form and position, and form the only part of the external surface which retains the ciliated epithelium.

Such are the general anatomical characters of the class *Annulata*, and such the progress each system of organs has made in the transit from the Nematoneurous to the Homogangliate types. The anellids are distributed into orders, according to obvious and easily recognisable modifications of the locomotive and respiratory organs; which characters fortunately coincide with the general conditions and grades of their organisation, and are therefore natural ones. Dr. Milne Edwards, the pupil of Cuvier who has devoted most attention to the Vermes thus grouped together by his great master, divides them into four orders.

The first is the *Annulata suctoria*, and comprises the leeches, which are provided with a suctorial disc at each extremity of the body, and have neither bristles nor tuberculate feet.

The second order is the *Annulata terricola*, which includes the earth-worms; these have neither tubercular feet, nor external gills, nor suckers, but are provided with short stiff bristles fulfilling the function of feet, and which, in fact, are the rudiments of such.

The third order is the *Annulata tubicola*, and includes all those which are provided with setigerous feet and have the respiratory organs at the anterior extremity of the body, whence they have also been called *Cephalo-branchiata*. The anellids of this and the two preceding orders can scarcely be said to have a distinct head.

The highest organised *Annulata* are also the most locomotive: they have been called *errantia* by Dr. Edwards. In them, the respiratory organs are most developed, and from their position, Cuvier, who first defined the order, has denominated it *Dorsibranchiata*, the gills being attached to the sides of the body on the dorsal aspect, along the middle part, or through the whole length of the body. They are provided with setigerous processes for locomotion, and have always a distinct head. They are commonly known by the name of Sea-centipedes, Sea-mice, or Nereids, from the Linnæan generic name *Nereis*, which is almost equivalent to the present ordinal term.

The tubular sheaths and protractile bundles of bristles which constitute the organs of locomotion in this order have been already noticed in the general characters of the class. The integument is naked, soft, vascular, and highly susceptible of impressions in all the anellids. It consists of a delicate non-ciliating epidermis, and of a moderately firm corium composed of obliquely crossing filaments. In some earth-worms the skin is red, from the colour of its contained or subjacent circulating fluids; in leeches it is variegated by a layer of pigment-cells; in most anellids the epidermis reflects iridescent tints, and in such it is readily detached from the cutis; but it closely adheres thereto in the *Suctoria*. In many *Errantia* the cutis developes filiform and lamelliform processes, and the latter, in some species (*Aphroditæ*), are so large and numerous as to overlap one another like scales. The hairs and bristles, already mentioned, are also developed, in some species, e. g. *Aphrodita aculeata*, so abundantly as to give it the mammalian character of a hairy investment, whence it has been called by our fishermen the "sea-mouse." The hairs of this beautiful anellid reflect brilliant iridescent hues.

In the tubicolar order the habitations are commonly formed of foreign substances, as particles of sand or shells agglutinated together by the mucous secretions of the worm, which is sometimes done with a considerable degree of neatness and apparent skill, as in the *Pectinariæ* and *Terebellæ*. The Serpula secretes a calcareous tubular shell, consisting of carbonate of lime and animal matter, like the shells of Mollusks; but differing in being quite external to the integument, and not organically attached to the animal, which can quit and return to its tube. Most species of *Serpulæ*, as the *Serp. contortuplicata*, which coats the shells of oysters and other bivalves with its characteristic dwelling, have a pedunculated operculum for closing the entry of the tube.

The organisation of the integument has been studied chiefly in the naked Anellids. It consists, in the leech, of a strong, smooth, whitish epiderm, and of a fibro-cellular corium divided into short segments, and having many pigmental cells of a brown or greenish colour, except in the intervals of the rings. The muscular fibres have a tendinous lustre: those of the outer layer are transverse; those of the next layer cross each other diagonally, and form a fine regular reticulation: beneath these are the longitudinal fasciculi, which form the most conspicuous stratum. There are also other smaller muscular fasciculi in the under surface of the body, besides those which specially regulate the action of the terminal suckers and the dentated jaws (*fig.* 102. *b*). The anterior border of the mouth is produced on the dorsal aspect, in the medicinal and some other leeches, so as to form a kind of upper lip, which combines with the rest of the muscular and verrucose border to form a sucker. In some sea-leeches (*Pontobdella*, *Piscicola*) the oral sucker is divided by a constriction or neck from the body. In *Branchiobdella* the pharynx is provided with a horny upper and under jaw. In the genus *Clepsine* a protractile flexible tube, like a proboscis, can be protruded from the bottom of the mouth. The mouth of the

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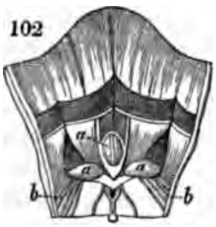
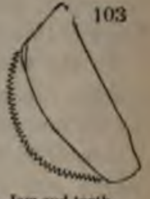
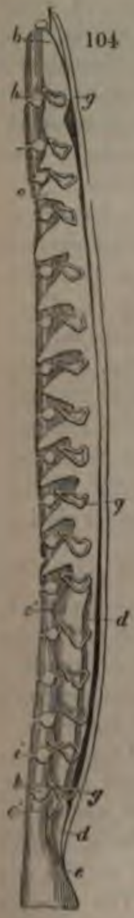


Leech.

medicinal leech (*Sanguisuga*) (*fig.* 102.), and of *Hæmopis*, is triangular, and is armed with three crescentic jaws (*a*, *a*, *a*), presenting their sharp convex margin towards the oral cavity, which margin is beset with sixty small teeth (*fig.* 103.). It is by the action of these little saws upon the tense integument seized by the labial sucker, that the characteristic triradiate bite of the leech is made.



Jaw and teeth. Leech.



Leech.

The œsophagus (*fig.* 104. *b*) is short, and terminates in a singularly complicated stomach, divided by deep constrictions into eleven compartments, the sides of which are produced into cæcal processes (*c*, *c′*), progressively, though slightly, increasing in length to the tenth, and disproportionately elongated in the eleventh compartment. The first gastric chamber is the smallest. In the eight posterior compartments the anterior part of each slightly expands to form a pair of small accessory cæca. The middle part of the eleventh division extends backwards, in the form of a small funnel-shaped process, and opens into the commencement of the slender intestinal canal (*d*, *d*); this is situated between the two last and longest gastric cæca (*c′*); it terminates by a small anus (*e*) above the terminal sucker.* This is the position of the vent in most *Suctoria;* but some sea-leeches (*Piscicola*) offer an exception in the ventral position of the outlet upon the last segment.

The modifications of the alimentary canal itself in other genera are considerable. In *Nephelis* it is a simple tube, gradually expanding towards the vent; in *Branchiobdella* the canal presents many circular constrictions; in *Pontobdella* it gives off a single pair of cæca near its hinder third; *Hæmopis* and *Clepsine* present the same multicæcal type of the canal as that which has been described and figured in *Sanguisuga*.

There is a stratum of round whitish glandular corpuscles, beneath the coats of the pharynx and œsophagus of the medicinal leech, which represents the salivary system. A peculiar brown tissue extends along the alimentary canal between the nervous chord and the mucous glands, and also upon the dorsal aspect of the anterior part of the cavity. It is composed of a congeries of elongated, convoluted, and irregularly constricted follicles, which are united in groups by the confluence of their ducts into a single slender excretory tube. These tubes unite with those of other groups of the follicles, and pour a secretion, analogous to bile, into the posterior divisions of the stomach and into the intestine. The confluence of the hepatic ducts is very remarkable and conspicuous when they lie upon the testes.*

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* See Preps. Nos. 442. 466, 467, 468. 569. 595. A.

The walls of the sacculated alimentary canal are connected with the integument by a vascular tissue, like the corpus spongiosum, mixed with many pigment cells. The chylaqueous fluid transuded into this tissue is there taken up into the largely developed vascular system.

Terricola.—The mouth is furnished in the earth-worm with a short proboscis, but is without teeth: a long lobulated salivary glandular mass surrounds the pharynx. The decaying parts of animals and vegetables are swallowed with the soil, and conveyed by a short and wide œsophagus to a muscular compartment of the digestive canal, analogous to a gizzard. The œsophagus is sometimes dilated, like a crop, above this part. The long and wide intestine is continued straight to the terminal vent, and is constricted in its course by the transverse septa of the common cavity of the body; but the sacculi are not produced into cæca.† Morren ‡ describes a long and slender blind tube, which he calls the "typhlosole," as being attached to one side of the inner surface of the gut, in which tube he supposes the chyle to be strained off from the coarse contents of the wider surrounding canal. A muscular compartment of the alimentary canal may be distinguished in *Nais proboscidea,* but not in *Lumbriculus* or *Enchytræus.* The latter worm has four pairs of clear vesicles, which pour their secretion into the gullet.

Errantia.—In this order the pharynx is developed into a loose and muscular cylinder, forming a kind of proboscis, provided with special muscles for its protrusion and retraction, eversion and inversion. It is short in *Nereis, Eunice,* and *Peripatus;* longer in *Glycera, Phyllodoce,* and *Polynoë.* In *Arenicola, Chætopterus, Aricia, Phyllodoce,* and *Amphinome,* the proboscis is unarmed: its everted extremity is encircled by small papillæ. In *Nereis, Lycastis,* and *Peripatus,* it is provided with a pair of strong, curved, horny jaws; and in other *Errantia* they are present in greater number: in *Eunice,*

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* CLXXXV. Bd. ii. p. 260. † Prep. No. 595. B. ‡ CCXII.

e. g., there are four on one side and three on the other side of the protractile pharynx: in *Lumbrinereis* there are eight jaws, and in *Aglaura* nine. These jaws are sharp-pointed and dentated on their inner border, and, when the pharynx is everted, they project externally, and can be used as prehensile organs. The *Tubicola* are edentulous.

The obliquity of the constrictions of the alimentary canal in the *Sabella pavonina*[*] give it the appearance of being a long and narrow tube disposed in a series of close spiral coils; but it is merely sacculated. In most other tubicolar anellids the intestine is less constricted than in the Sabella; and in *Amphitrite* it is uniform, irregularly convoluted, and loosely suspended in the abdominal cavity.

In the *Terebellæ nebulosa* and *conchilega* the wide and long œsophagus is coated by a yellow glandular mass, and is separated from the slightly sacculated yellow gastro-intestinal tube by an elongated colourless gizzard. In the *Hermella* there is a short oval dilatation or stomach between the œsophagus and intestine.

In the sand- or lug-worm (*Arenicola*) the gastro-intestinal canal (*fig.* 106.) commences at the termination of the œsophagus (*b*) by a sudden dilatation, into which two cæcal glandular pouches (*c*) pour their secretion: the rest of the canal is simple in its outward form; but its walls are thickened by a stratum of minute secerning cells (*d*), which prepare a greenish-yellow fluid. The œsophagus can be everted and protruded; the sand is seized and swallowed as the worm bores its way; the organic particles are assimilated as the earthy medium traverses the digestive canal, and it is finally rejected in the form of the sand coils, which betray the retreats of the "lugs" on the sea-strand.

In most of the Errantia there is no distinction between stomach and intestine; this runs straight to the terminal vent in *Eunice* and *Amphinome*, as in *Arenicola*: in *Cirratulus* it takes a spiral course; and it is irregularly convoluted in *Ammotrypane*. In some Nereids the canal is provided with lateral pouches, a pair of which, in *Nereis* proper, open into the compartment of the canal which answers to the stomach. The intestinal canal is lined by a ciliated epithelium in all anellids. In the *Aphrodita aculeata* the part homologous with the projectile proboscis of the Nereids is converted into a kind of gizzard, by the thickening of the muscular coat. The alimentary canal, continued from its posterior extremity, bends forward at first for half the length of the gizzard, a disposition which indicates the occasional protrusion of this part. The canal then bends backwards, and is continued straight to the anus. Through the whole length of the intestine, cæcal processes are sent off on each side, to the number of about twenty pairs. They commence of a slender diameter, but gradually enlarge, send off many short branches, which subdivide, and terminate in fusiform pouches. These productions of the intestinal canal are homologous with the gastric cæca of the leech; but they are more isolated from the common canal, and more distinct in their functions. It is thought that the chyme passes into them, and that the chyle is separated from it by a secretion of the terminal cæca analogous to bile. Hunter has placed a preparation* of them at the commencement of his series of hepatic organs, as one of the early forms of that system.

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[*] No. 441.

The more unequivocal form of hepatic organ is that yellowish or brownish glandular mass which surrounds almost the whole intestinal canal in most Anellides, and which consists of aggregated follicles, opening either singly or by a duct common to several, upon the inner surface. These follicles give a villous character to the outer surface of the gut in *Enchytræus;* their homologues form the part called "chloragogena" by Morren in the *Lumbricus.* In *Amphitrite* the follicles are of a bright yellow colour.

The abdominal cavity is obliterated in the suctorial Anellids by the spongy vascular tissue uniting the sacculated alimentary canal to the skin: in the *Terricola* it is divided into numerous small compartments by the septa, which closely connect the intestine with the skin: it is also more or less subdivided by the incomplete septa and the muscles of the setigerous sheaths in the higher Anellides; but all the recesses and ramifications of the abdominal cavity intercommunicate freely with each other. In this complex space there is a colourless fluid containing organic corpuscles, which is kept in constant motion by the varying contractions and dilatations of the surrounding segments, a ciliated epithelium being rarely present, as *e. g.* in *Aphrodita aculeata;* or only partially developed upon the peritonæum, as, *e. g.* in the part lining the tubular feet of the Hermellæ†, and the hollow branchiæ of the *Glycera.* This fluid answers to the chylaqueous fluid of the Radiata.‡ In the Errantia it performs one of the functions of an internal skeleton, acting as the fulcrum or base of resistance to the cutaneous muscles, the power of voluntary motion being lost when the fluid is let out; the vermicular motions of the intestine are aided or determined by its resistance and support;

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* No. 782.

† CXC. p. 36.

‡ Ib. pp. 170—173., where different forms of the chylaqueous corpuscles are described.

it favours circulation by obviating the pressure upon the blood-vessels, which would follow the contact of the intestine with the integument, and is, perhaps, the source, or one of the sources, of the blood itself. Besides the organic and definitely shaped corpuscles, it contains albumen, fibrine, and also crystalline products identical with those obtained by evaporation of pure sea-water, and, therefore, merits, as in the Polypes and Echinoderms, the name of the chyl-aqueous fluid. Dr. Williams believes that "sea-water is vitalised with wonderful facility by the solid organic elements contained in the chylo-peritoneal fluid."*

In the majority of the Anellids the blood is red; in some of a brilliant red, as in *Arenicola*, *Nereis*, *Glycera*, *Nephtys*. In *Aphrodita* and *Polynoë*, the blood is of a pale yellow colour; in a species of *Sabella* it is olive green; so that, as Milne Edwards well observes, the colour of the blood is far from being a character of such physiological importance as to justify the location of the Anellides at the head of the articulate sub-kingdom. Dr. Williams denies that the blood of the Anellides contains any coloured or other corpuscles. It circulates in a closed system of arteries and veins, the modifications of which are considerable when examined in the different genera of the class.

A large vessel which runs beneath the dorsal integument is the seat of undulating contractions, by which the blood is propelled from behind forwards; it fulfils the functions of the heart, and is the homologue of the dorsal vasiform heart in insects. A corresponding venous trunk conveys the blood in an opposite direction from the head to the tail, along the under or ventral surface of the abdominal cavity. These are united at each segment by transverse vessels, which convey the fluid from the ventral vein to the dorsal artery: the latter or annular circulation is often aided by the contractile walls of partial dilatations of certain of the vessels, and by the actions of the gills themselves in the higher anellids.

In the leech the vascular system consists principally of four great trunks, none of which present any local dilatations meriting the name of heart; one of these trunks is situated on each side, a third above, and a fourth below, the alimentary canal. They are shown in transverse section, as connected together in two of the middle segments of the leech in the diagram (*fig.* 105.), from Brandt's Monograph.† The lateral trunks (*c*, *c*) are the largest; they are widest in the posterior third of the body; their anterior end terminates in branches to the head; the posterior end unites with that of its fellow

* CXC. p. 173. † CLXXXV.

more conspicuously than at the anterior part, and supplies the terminal sucker. Branches are given off at each ring, which almost immediately divide into a dorsal (*d*) and ventral (*e*) ramulus; the six posterior dorsal branches unite with those of the opposite side, and the six arches thus formed are joined together by two nearly parallel longitudinal vessels near the middle line of the back.

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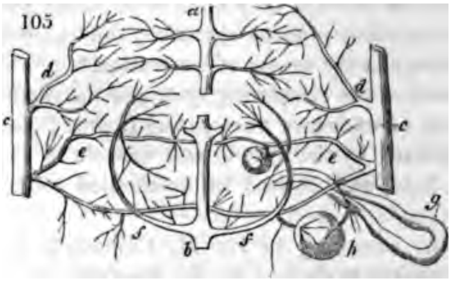

Leech.

The dorsal vessel (*fig.* 105. *a*), in which the blood moves from behind forwards, is formed by the union of the dorso-intestinal vein and of the dorso-dermal vessel, which run parallel with each other along the posterior third of the body. The trunk is thence continued forwards, sending outwards a pair of transverse branches at each ring, and bifurcating behind the mouth to enclose the œsophagus. From the under part of the œsophageal ring the great ventral vein (*fig.* 105. *b*) begins, which is continued along the nervous ganglionic chord, and swells at each ganglion, forming a sinus around it; the nervous matter being thus, as it were, bathed in the nutrient fluid.* From each of these swellings a transverse branch is sent off to either side (*f*, *f*), and from the seventh to the fifteenth ganglionic sinus a second pair of transverse vessels of smaller size is given off, just behind the ganglionic sinus.

The respiratory function would seem to devolve partly upon the tegumentary capillaries, and partly upon those capillaries which spread upon the mucous sacculi. These latter capillaries are not, however, more numerous than those of the other organs of the body. The more important office of the sacculi would seem to be as the recipients of the secretion of peculiar loop-shaped glands, which they receive by a very short and slender duct. There are seventeen pairs of these mucous glands (*figs.* 104, 105. *g*, *g*), the five posterior of which lie on each side the long terminal gastric sacculi, and the rest in the interspaces of the shorter cæca. Each gland pours its secretion into a circular sac (*figs.* 104, 105. *h*, *h*), which opens externally (*fig.* 104. *i*, *i*) upon the skin. These dermal pouches have commonly been described as the respiratory organs; and from their relative position they may be deemed homologous with the tracheal respiratory organs of the higher *Articulata;* but in fanction they seem to be reduced to supplying the skin with its abundant mucous secretion, and the ova with their cocoon-like coverings at the season of generation.[*]

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* CLXXXIV. p. 114.

Morren has minutely described the circulating system of the earthworm; in a species of which (*Lumbricus variegatus*) Bonnet[†] saw the red blood propelled forward by the systole and diastole of the dorsal vessel towards the head, and noticed its accelerated course near that part.

In the tubicolar anellids, according to Dr. M. Edwards[‡], the dorsal contractile artery is unusually short. In the *Terebella* it receives numerous veins from the intestine, and a large accession of the circulating fluid from two wide transverse venous trunks, which encircle the commencement of the intestine, and which receive recurrent veins from the œsophagus, also a small vein from the integuments of the back. This short dorsal vessel is, in fact, the general receptacle of the venous system, and, by its function, it represents a pulmonic heart. It transmits the venous blood almost exclusively to the cephalic branchiæ by three pairs of branchial arteries, which arise from its anterior extremity. The oxygenated blood is returned by the branchial veins to a large ventral trunk, situated immediately above the ganglionic nervous chord. This vessel, which has the function of a systemic heart or aorta, supplies a pair of transverse branches to each ring of the body, which distribute filaments to the integuments and the feet, and then ascends to supply the intestine, where, with the absorbent veins of that canal, it returns again into the dorsal vessel. In some other species of Terebella, as the *Ter. conchilega*, the lateral branches of the ventral trunk do not ascend in loops upon the upper surface of the intestine, but terminate almost exclusively in a vascular network situated on each side of the abdominal cavity near the base of the feet. The principal organs of impulsion of the circulating fluid in the tubicolar anellids seem to be the contractile branchiæ, which thus combine, as it were, the functions of both heart and lungs.

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[*] Dr. Williams (CXC. p. 257.) affirms that "spermatozoa can always be discovered in the interior of these sacs;" and states that they are "true vesiculæ seminales." I have never been so fortunate as to detect spermatozoa in the mucus-sacs of young leeches, in which those parts have been relatively as fully developed as in the full-grown leeches fit for copulation. The looped glands (*g*) are described by the same writer to be ovaria, "ovarian utricles," the glandular granular particles, enclosed in their walls, which are figured and described by Brandt and Ratzeburg (CLXXXV. "Drusensubstanz," p. 251, tab. xxix. A. fig. 8), having apparently been mistaken for ova. Dr. Williams further describes a minute duct as extending outwards, crossing beneath the longitudinal sperm-duct, and "becoming united to the base of the ovarian utricle," p. 254 (looped mucus-gland, *g*). Although my dissections have enabled me to distinguish the small blood-vessels uniting the testes to a neighbouring mucus-duct, I have failed to make out the sperm-duct so described.

[†] Observations sur les Vers, Œuvres, i. p. 193., 1779.

[‡] Sur la Circulation dans les Anellides, Annales des Sciences, Nat. X. p. 121.

Cuvier has noticed the alternate expansion of the branchiæ of the *Arenicola* when they are coloured by the bright red blood, and their contraction, when, by expelling the blood to the internal vessels, they become of a pale grey colour.

In the *Eunice sanguinea*[*] there is, as in the *Terebella*, a large and short dorsal vessel, which rests upon the pharyngeal part of the alimentary tube, and which communicates, by its posterior extremity, with a vascular ring surrounding the commencement of the intestine. This ring receives two vessels, which run parallel and close together along the dorsal aspect of the intestinal canal, and correspond with the single vessel in the *Terebella*. The dorso-pharyngeal contractile trunk receives other branches from the parietes of the digestive tube, and a small medio-dorsal cutaneous vessel. It gives off by its anterior extremity several branches to the head, and others which surround the pharynx, and anastomose with the ventral vessel. From this vessel a pair of lateral branches is given off at each ring of the body. These branches immediately dilate, and are bent upon themselves in a strong sigmoidal curve, appearing at first sight to be simple oval vesicles. They send an ascending branch to the digestive tube, form a small plexus at the base of each of the feet, and penetrate the branchial filaments. The blood is returned from these respiratory organs by transverse veins, which terminate on each side in the dorso-intestinal vessel of that side. Here, therefore, the respiratory circulation is removed further from the dorso-pharyngeal heart, which consequently receives a greater quantity of blood in its arterial or oxygenated state. The principal dynamical organs are, however, the curved dilated sinuses at the bases of the branchiæ, which pulsate with strong contractions, and propel the blood at once to the branchiæ, the feet, the skin, and the intestine. If we call these pulsatile reservoirs by the name which their functions would claim for them, there will be several hundred hearts in one of these gigantic Nereids. In the *Nephthys Hombergi* the dorsal vessel is double throughout the greater part of its extent.

In the *Amphinome capillata*, which Hunter has here[†] dissected for the vascular system, this is chiefly remarkable for the size and complexity of the branchial plexuses.

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[*] Edwards, loc. cit. p. 204. [†] Preps. Nos. 875. 889, and x. pl. xiv. fig. 10.

In the *Arenicola* (*fig.* 106.) there is, on each side the base of the œsophagus, an ovoid contractile sac (*f*), which sends off a large and short vascular trunk downwards and backwards to the medio-ventral line, where, uniting with its fellow trunk, a ventral vessel (*e*), analogous to that in the *Eunice* and *Terebella*, is formed. This median vessel furnishes a pair of transverse branches to each ring, which at the seventh segment begin to penetrate the ramified branchia, attached to the sides of that and succeeding middle segments of the body. The pulsations of the two œsophageal sinuses, or ventricles, propel the blood into the ventral vessel from before backward through these vessels (*m, m*) to the gills, where it receives a new impulse by the contractions of these organs, and, after having been oxygenised, it is returned, partly by cutaneous vessels, which form many anastomoses, and chiefly by a direct and continuous lateral vessel (*k, k*), to the medio-dorsal intestinal artery (*g*). This artery extends from one end of the body to the other. At its middle part it receives many transverse branches from the digestive tube, and through them anastomoses with the inferior intestinal vein (*h*). The vascular network thus formed around the intestine, gives origin anteriorly to two lateral veins (*i*), which terminate in the dorsal vessel immediately behind the œsophageal ventricles. The blood from the inferior intestinal vein is conveyed to the same point or sinus. After the communication of this common sinus with the two hearts, a slender median vessel (*g*′), a continuation of the dorsal one, extends forwards towards the head, and terminates by forming two vascular rings around the base of the proboscis, from the lower part of which the ventral vessel arises, which vessel (*e*), passing backwards, receives the great accession of blood from the two contractile hearts, and thus the circulation is completed.

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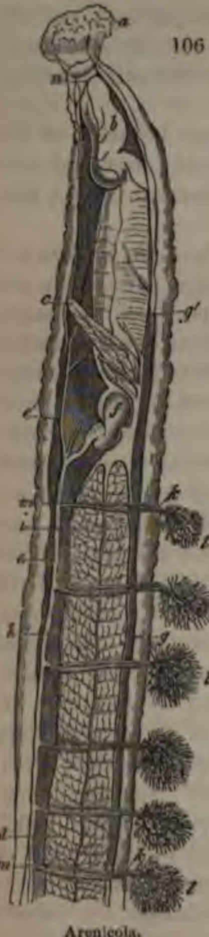

Arenicola.

This has much analogy with the circulation of the blood in the earth-worm, in which the blood travels from behind forwards in the dorsal vessel, and descends in great part towards the ventral vascular system through the pairs of anterior beaded contractile sinuses or hearts[*], which differ only from the two ventricles in the *Arenicola* by their greater number. In the lateral vascular canal, which extends along the anterior part of the body, at the base of the feet in the *Arenicola*, and which is formed by the anastomoses of one of the branches of the cutaneous arteries, we have the homologues of the lateral vessels in the leech tribe, which are wanting in most of the higher Anellides. The dorsal and ventral trunks are common to all, and in most there are four longitudinal vessels attached to the intestinal tube.

The most striking physiological character of the circulation in the Anellides as a class, is the continuity of their capillary system, and the difficulty of determining which is the arterial, and which the venous trunk of any one of the organs or parts of the body, excepting the branchiæ. There alone, we find that the blood received from the distinct artery is sent back by as distinct a vein, which returns along the same route as the artery, as it does in the limbs of the higher animals. By the rapid division and general system of anastomoses of the arteries and veins, it follows that almost all the parts of the body are supplied by a mixture of arterial and venous blood.

The position and general relations of the branchial organs have already been incidentally pointed out; and it seems only necessary here to allude to their different forms. In the leech and earth-worm, a series of pores or stigmata on each side of the body lead to as many simple sacculi (*fig.* 104. *h*, *h*), formed by an inward folding of the integument. Carry the duplicature further in, divide and subdivide it, and ramifications of air tubes, like the tracheal respiratory system of insects, would be produced. We may perceive in the lateral sacs of the leech and earth-worm, the first step, morphologically, in the development of the very peculiar air-breathing organs of the higher Articulata; but, in their actual rudimentary form, their respiratory functions are reduced to the lowest state, and they serve chiefly the office of excretory organs, preparing and discharging mucus. In *Branchiobdella* a pair of looped canals open at the beginning of the middle third-part of the body, and a second pair at the hinder end of the body, both at the median line of the under surface. Close behind the orifice each of these four canals expands into a round yellow-coloured sac, from which many convoluted tubes proceed. They are lined by a ciliated epithelium. A greater number of such pairs of organs are found in other leeches at the second third-part of the body, one behind another as far as the posterior extremity:

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[*] See Preps. 876, 877, 878.

those in *Nephelis* are not ciliated. In the earth-worm there are on each side of the commencement of the intestine many looped tubes which open externally by a small orifice on the under surface on one side of the middle line, and have their inner surface beset with festooned ciliated ridges. They are dilated near the orifice, and contain a clear fluid, kept in movement by the action of the cilia; which fluid the worms may obtain from the moist earth. These "water-canals" are surrounded in *Lumbricus* by a remarkable plexus of vessels, to which numerous pedunculated blood-receptacles are appended, giving the whole system a racemose character. Similar blood-sacs are appended to the same system of vessels in *Nephelis vulgaris;* but such sacs are simple reservoirs, and have no pulsation.

The respiratory organs of the tubicolar anellids are in the form of long, flattened, and sometimes tortuous, filaments* which radiate from the head, generally in two lateral fasciculi, disposed in a funnel-shaped or spiral form. When not coloured by the red circulating fluid, they are often barred and variegated by bright purple, green, and yellow tints, forming a rich and gorgeous ornamental crown. Each filament, in *Serpula, Sabella*, and *Amphitrite*, is fringed by a row of actively vibrating cilia, which effect the requisite change of the respiratory medium in contact with the vascular surface. In *Amphitrite* they are semipinnate. In *Terebella* the branchial filaments are florid blood-vessels, inclosed in a delicate non-ciliated integument. The cephalic tentacles, which are hollow, and are penetrated by the chylaqueous fluid, expose an extensive surface to the surrounding medium, which must react on the contained fluid, and thus aid in respiration.

The branchiæ of the *Annulata errantia* are usually in the form of shorter tufts than the cephalic ones of the *Tubicola*, and they are attached to the upper parts of the sides of a greater number of segments. The following descriptions of some of their chief modifications are from the excellent "Report on the Anellida" above cited. "Respiration is performed in *Arenicola Piscatorum* by means of naked blood-vessels, projecting at the root of the setiferous process upwards and outwards one-fourth of an inch in the adult worm from the surface of the body. They are limited in number and distribution to the fourteen or sixteen middle annuli of the body. They are commonly described as forming an arborescent tuft; the division of vessels is however regulated by a fixed principle. When fully injected with blood, the vessels of each branchia form a *single* plane, rising obliquely above and across the body, and immediately behind each brush of setæ. In the adult animal each gill is composed of from twelve to sixteen primary branches, proceeding from a single trunk, which arises from the great dorsal vessel; the vessels in the branchial tuft describe *zigzag* outlines; the secondary branches project from the salient point, or the outside of each angle of the zigzags; and the tertiary from similar points on the secondary branches. This mode of division, occurring in one plane, and in all the smaller branches, results in a plexus of vessels of extreme beauty of design. Each branchial tuft and each individual vessel possess an independent power of contraction; in the contracted state the tuft almost entirely disappears, so completely effected is the emptying of the vessels. The contraction, or *systole*, in any given tuft occurs at frequent but irregular intervals; this movement does not take place simultaneously in *all* the branchiæ, but at different periods in different tufts. As there is no heart-like dilatation in the afferent vessels of the branchiæ, the contractile power with which the exposed branches are endowed, becomes an important means of reinforcing the branchial circulation. The vessels appear quite naked, and if examined in the living state, each ramuscule seems to consist only of a single trunklet; if this were really the case, it would of course resolve itself into a tube ending in a cul-de-sac, and the blood movement would be a flux and reflux; but by injection it is easy to show that the finest division of the branchial arbuscle contains a *double* vessel, enveloped in a common muscular, although extremely diaphanous sheath. That these vascular sheaths, which are only fine productions of the integuments, are furnished with *voluntary* muscular fibres, is proved by the rapid and simultaneous retraction of *all* the branchiæ into the interior of the body, which follows when the animal is touched.

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* Prep. No. 990.

" The genus *Eunice* presents another and different type of branchial vessels. Arranged in a prominent row of bright vessels, standing erect as minute combs at the dorsal base of each foot in the body, the branchiæ impart to all the species of this genus a graceful and characteristic appearance. In every species the branchial vessels divide on a uniform plan *peculiar* to this genus. The primary trunk rises vertically along the inner side of the branchia, and sends off from its outer side, at intervals, *straight* vessels, which gradually decrease in size from below upwards; each branch forms a straight undividing vessel, curving gently upwards and towards the median line: these branches become in their number characteristic and distinctive of species. In some of the smaller species inhabiting the British coasts, the branchiæ are composed only of a single vessel;

this is the case also with the *young* of the larger species; in others they vary from the single vessel to the number of six or eight.

"In the genus *Lycidice* the branchia consists of a flat lanceolate process, more or less developed, surrounded marginally by a blood-vessel, the mid-space between the lines of the advancing and returning vessels being composed of large-celled tissue, lacunose, into which the peritoneal fluid penetrates by a flux and reflux movement. The branchiæ in *L. Ninetta* are situated dorsally, and are supplied at their bases with single rows of vibratile cilia. Those of *Aglaura fulgida* are similarly constructed, although they differ slightly from those of the former genus in size and figure. In *Œnone maculata* they occur under a more developed form, constituting flattened, pointed, trowel-shaped processes, the plane of which is vertical with reference to that of the body. A blood-vessel, as in the former cases, trends along the borders, immediately beneath the cuticle. The course of these vessels is followed by a row of large and prominent vibratile cilia.

"In the branchial system of the genus *Nereis* (Cuv.), *Lycoris* (Savigny), the anatomist encounters a structure strikingly different from anything hitherto described. Whether round or laminated, the true branchiæ in this genus are always penetrated by the fluid of the visceral cavity, and the blood-vessels assume a peculiar disposition. When the branchial process is conical in shape, its base is embraced by a *reticulated* plexus of true blood-vessels, which is situated quite superficially and immediately beneath the epidermis. These vessels are most prominently developed on the dorsalmost process, which, therefore, may be called the branchial; but they extend more or less over all the cirri. A better characteristic of the branchiæ, both the conical and the foliaceous, in the *Nereids*, is that of their being penetrated by the peritoneal fluid. In those species in which the branchial process is round, the interior of the base is hollow, and filled with the fluid of the visceral chamber. Floating in this fluid may be seen, when viewed transparently, coils of naked blood-vessels: in those in which they are laminated or foliaceous, as in *Nereis renalis*, the step of the exterior surface does not extend beyond the limits of the base; the flat portion, however, is tunnelled by straight spacious canals, which radiate with great regularity from the base to the expanded circumference of the process. In these canals the corpuscles of the peritoneal fluid may be seen rolling to and fro, advancing and returning in the same channel. These movements are regulated by those of the great current in the chamber of the peritoneum. This type of structure prevails in *Nereis renalis*, *N. longissima*, and in a slightly modified form, in consequence of the less flattened shape of the branchiæ, in *N. viridis.* The *round* variety of branchial processes obtains in *N. margaritacea, N. Dumerillii, N. fucata, N. pelagica,* and *N. brevimanus.* It is a fact difficult to explain that the branchial organs in the *Nereids* should be destitute in every species of vibratile cilia.

"The laminated or foliaceous type attains the point of its maximum development, in the branchial appendages of the genus *Phyllodoce.* Rich leaf-like projections, it was difficult to assign any other than a respiratory use to these parts in these beautiful worms. The branchiæ in *Phyllodoce viridis* are prominent dorsal appendages: in this worm the blood-system can be traced only by a few scanty vessels distributed over the roots of these processes; nor are the canals very spacious and distinct, they are more like lacunæ in a spongy tissue. In *P. bilineata* and *P. lamelligera,* the radiating passages, distinct from each other and communicating only indirectly through cells, are extremely obvious under the microscope. They carry the fluid of the peritoneal cavity, the corpuscles of which may be seen flowing and ebbing in the same channel. Nothing can, however, more conclusively prove the true branchial character of these laminæ than the presence of cilia, the vibrations of which can be observed only at the edges of the respiratory laminæ. These are best seen in *P. lamelligera.* This is a striking point of distinction between the *Phyllodoce* and the *Nereids,* in which vibratile cilia on the branchiæ have no existence. The peritoneal fluid, then, may be affirmed as that, in the economy of the *Phyllodoce,* which is the subject exclusively of the respiratory function, the true blood receiving its supply of oxygen from this fluid, afterwards to convey it to the solid structures of the body.

"In the genus *Glycera* the blood-proper is entirely excluded from the organs of respiration. This office devolves exclusively on the chyle-aqueous fluid, which in nearly all the species of this genus is profusely supplied with *red* corpuscles. The gills consist of hollow cylindrical appendages, emanating from the base of each dorsal foot at its superior aspect, filled in the interior with the fluid of the visceral cavity; but what is remarkable in the structure of these organs and quite peculiar to this genus, is that the *interior* parietes of the cylindrical hollow of the branchiæ is lined with vibratile cilia; these motive organules cause the corpuscles of the fluid by which the branchiæ are penetrated, to move with great rapidity in a definite direction, viz. peripheradly on one side and centradly along the other, each corpuscle whirling on its own axis as it proceeds. Ciliary vibration cannot be detected on the outside of the branchial appendage.

"In the *Syllidæ* the branchial organs are penetrated by the peritoneal fluid; but it can be detected in motion only in the bases of the cirri, and these parts only are furnished with vibratile cilia, which are large and active. The long filiform and, in some species, moniliform appendages, which are described commonly as the branchiæ of these Annelids, are not hollow; they are filled with large-celled tissues, through which the fluid parts of the contents of the visceral cavity slowly percolate. In the Syllidan family, which excels all others in grace and beauty, the proper blood-system is almost indetectible, in consequence of the colourlessness of the contents. It may be stated with confidence, that blood-vessels do not enter into the structure of the branchial processes. The respiration therefore devolves exclusively on the chylo-aqueous fluid.

"Amongst the family *Ariciadæ* several other varieties in the configuration of the breathing organs occur. In the genera *Leucodore*, [illegible], and [illegible], the branchial appendages affect a dorsal situation. In these genera they are traversed from base to apex by a single blood-vessel returning upon itself. This vessel, however, is supported by a bundle of spongy tissue, into the cells of which the fluid of the visceral chamber penetrates. The office of respiration in this family is therefore discharged in part by the blood and in part by the chylaqueous fluid. In every species of this family the branchiæ are supplied by vibratile cilia having a distinct disposition in each. *Leucodore ciliatus*, on the dorsal aspect and over the posterior two-thirds of the body, is covered on each side with a row of flattened conical branchial processes, blood-red in colour and richly ciliated. They are largest anteriorly, and smallest near the tail. The cilia are disposed in a spiral line, from the attached to the extreme end. Viewed with a high magnifying power, and transparently, a camerated axis, composed of exquisitely fine hyaline cartilage, may be discovered, fulfilling on the branchiæ of this elegant little boring Annelid the office of mechanical support, as a similar structure was formerly shown to do in those of the *Sabellæ*.

"In the genus *Nerine* the respiratory organs occur under forms of the highest beauty. They constitute flat, membranous, penknife-shaped appendages, curving gracefully over the back with the curve of the "ring" of the body by which they are supported, and crossing over the dorsal median line, and alternating with the corresponding process of the other side. The *plane* of each process is vertical in relation to the longitudinal axis of the body; they lie, therefore, one over the other in an imbricate manner. They are less flat and close in *N. vulgaris* than in *N. conioce phala*. They are largest in size towards the middle of the body, smallest anteriorly and posteriorly.

The blood-vessels, the afferent and efferent, run close to and parallel with the inferior border of the process; the upper part of each is composed of a membranous lobular addition to the inferior and vascular portion. Into the cells of this lobule the chyle-aqueous fluid slowly finds its way, and participates obviously in the office of respiration. In *N. coniocephala* it is remarkable that the cilia should be limited in their distribution to the margin, along which the true blood-vessel runs. This fact is less manifest in *N. vulgaris*, in consequence of the smallness of the membranous lobule. In *Aricia Cuvieri* the branchial appendages are more conical in figure, more vertical in position, and developed only at the posterior four-fifths of the body. They are covered with large vibratile cilia, which likewise extend over that segment of the dorsum which separates the bases of the branchiæ. Like those of the preceding genera, they are supplied with spongy tissue for the exposure of the peritoneal fluid.

"It may have been remarked, that in all the members of the preceding family the real branchial organ has consisted of an evolved or exaggerated development of the *superior* element of the dorsal foot. In the genus *Nephthys*, which comes now under review, it is the inferior element of the dorsal foot which becomes the subject of this evolution. *Nephthys Hombergii* of our coasts is a remarkably vigorous and active worm, and yet its organ of breathing consists only of a comparatively small *curved* ciliated process, situated under cover of the dorsal foot, and carrying only a single-looped vessel. It may be mentioned, as an interesting proof of the real appropriation of this process in *Nephthys* to the function of breathing, that the *same* process, although *similarly shaped*, on the ventral or inferior foot, is *not* provided with cilia, nor is it penetrated by any blood-vessel.

"The genus *Cirrhatulus* of Lamarck, and the allied group constituted by Savigny under the name of *Ophelia*, introduce to the physiologist another modification of the branchial organs within the limits of the dorsibranchiate order. As in the preceding families, they are in these latter only 'developments' of the dorsal cirri. In *Cirrhatulus Lamarckii*, a linear series of yellowish and blood-red threads, remarkably irritable and contactile, project to a considerable distance, from each side of the body, thoughout its whole length; at the occiput, however, they are arranged in a crown-like form. These beautiful filaments, which are obviously designed to fulfil the twofold office of touch and respiration, appear under the microscope to consist only of a single blood-vessel inclosed in a delicate sheath of integument. Closer analysis, however, discovers *two vessels* in each of these filaments, and traces of longitudinal and circular muscular fibres in the investing sheath. By the contraction of this sheath, the inclosed vessels may be completely emptied of their blood from one end of the filament to the other. This contraction does not take place simultaneously in every part, but undulatorily, the wave motion beginning at the extreme fore-end. It is especially to be noted, that, in this variety of appendage, in which the respiratory is only an incidental function, there exist *no vibratile cilia.* These organs in *Ophelia coarctata* exhibit analogous characters, while they are less numerous and much shorter.

"The *Aphroditaceæ* constitute a group of Annelids to which the term 'dorsibranchiate' by no means correctly applies; that is, in the majority of the species embraced in this order, no branchial appendages exist, either on the dorsum or any other part of the body. Respiration is performed on a novel principle, of which no illustration occurs in any other family of worms. In all *Aphroditaceæ* the blood is colourless. The blood-system is in abeyance, while that of the chyle-aqueous is exaggerated. Although less charged with organic elements than that of other orders, the fluid of the peritoneal cavity in this family is unquestionably the exclusive medium through which oxygen is absorbed. The true Aphrodite type of respiration occurs in *Aphrodita aculeata.* In this species the tale of the real uses of the 'elytra,' or scales, is plainly told. Supplied with a complex apparatus of muscles, they exhibit periodical movements of elevation and depression. Overspread by a coating of felt readily permeable to the water, the space beneath the scales during their elevation becomes filled with a large volume of *filtered* water, which during the descent of the scales is forcibly emitted at the posterior end of the body. It is important to remark, that the current thus established *laves only* the *exterior* of the dorsal region of the body. It nowhere enters the internal cavities; the latter are everywhere shut out by a membranous partition from that spacious *exterior* inclosure bounded above by the felt and the elytra. In this species the peritoneal chamber is very capacious, and filled by a fluid which only in a slight degree contains organised particles. The complex and labyrinthic appendages of the stomach lie *floating* in this fluid, and in the chambers which divide the roots of the feet. From this relation of contact between the peritoneal fluid and the digestive cæca, *which are always filled by a dark green chyle,* it is impossible to resist the conclusion that the contained fluid is really a *reservoir* wherein the oxygen of the *external* respiratory current, already described, becomes accumulated. From the peritoneal fluid the aërating element extends in the direction of the cæca, and imparts to their contents a higher character of organisation. These contents, thus prepared by a sojourn in the cæca of the stomach, become the direct pabulum for replenishing the *true* blood which is distributed in vessels over the parietes of these chylous repositories."

The rythmical elevation and depression of the respiratory scales of the Aphrodite are interesting facts, and we shall afterwards see their homologues taking an important share in the locomotive functions of the higher organised forms of *Articulata*.

Most Annelids exude a tenaceous mucus from the skin; the excretory follicles are arranged in curved rows on both the dorsal and ventral aspects of the rings in the leeches and larger earthworms.

The precise locality of the secretion of the horny or leathery tubes of certain Annelids is not yet understood; but the tumid ridge around the first segment of the *Serpulæ*, seems to be the formative organ of the calcigerous cells in the production of the shelly sheath. Four yellowish glands, terminating by a common orifice on the first body-segment of the *Amphitrite*, most probably prepare the mucous cement, by which the particles of sand and shells are attached together to form their neat artificial tubes. The long and delicate cephalic tentacles of the *Terebellæ* take an important share, hardly to be suspected at the first glance, in the nidification of these humble sea-worms. "They consist," writes Dr. Williams, "in *T. nebulosa*, of hollow flattened tubular filaments, furnished with strong muscular parietes. The band may be rolled longitudinally into a cylindrical form, so as to inclose a hollow cylindrical space, if the two edges of the band meet; or a semi-cylindrical space, if they only imperfectly meet. This inimitable mechanism enables each filament to take up and firmly grasp, *at any point of its length*, a molecule of sand; or, if placed in a linear series, *a row* of molecules. But so perfect is the disposition of the muscular fibres at the extreme free end of each filament, that it is gifted with the twofold power of acting on the sucking and on the muscular principle. When the tentacle is about to seize an object, the extremity is drawn in, in consequence of the sudden reflux of fluid in the hollow interior; by this movement a cup-shaped cavity is formed, in which the object is securely held by atmospheric pressure; this power is, however, immediately aided by the contraction of the circular muscular fibres. Such, then, are the marvellous instruments by which these peaceful worms construct their habitation, and probably sweep their vicinity for food."*

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* CXC. p. 194.

LECTURE XII.

ANNULATA.

HITHERTO the highest condition of the nervous system which we have observed, has been that of detached unganglionic filaments diverging from a single sub-œsophageal ganglion or from a simple œsophageal ring, continued unconnectedly along the abdomen, or diverging in rays down equidistant tracts of the common parietes of the body. If we have met with ganglionic masses in connection with coloured ocelli, these have been, as, e. g., in the Acalephæ, either so situated as to give no indication of a head, or so multiplied as to lose all significance as a common cerebral centre of sensation.

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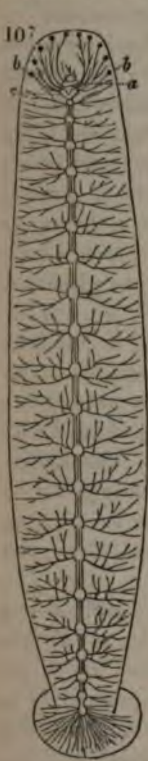

Leech.

In the class *Annulata*, the nervous system has reached a higher type and more constant plan of arrangement. It always commences by a symmetrical bilobed ganglion, meriting, both by its situation above the mouth and by the parts which it supplies, the name of brain, which it has commonly received. The sub-œsophageal ganglion is, however, the analogue, if not the homologue, of the medulla oblongata, and should be included in the encephalic division of the nervous system in both the Articulate and Molluscous animals.

In the medicinal leech there are sent off from the super-œsophageal ganglion (*fig.* 107, *a*) ten distinct optic nerves (*b b*), besides many smaller filaments to the integument and other parts of the head; each optic nerve or filament terminates by expanding upon the base of a black eye-speck or ocellus, ten of which you will easily distinguish by the aid of a moderate magnifying power, dotting at equal distances the upper margin of the expanded suctorial lip.

The principal nervous productions of the brain of the leech are what may be termed its crura, which diverge as they descend to embrace the œsophagus, and are called the œsophageal chords; they then converge and reunite to join the large cordiform sub-œsophageal ganglion (*c*). From this ganglion the muscles of the three serrated jaws, as well as the principal muscles of the oral sucker, derive their nervous influence. Those who have watched the vigorous workings of this part in a hungry leech beginning its parasitic feast, will not be surprised at the great development of the nervous centre of the suctorial and maxillary mechanism. Two chords, in such close apposition as to seem a single nervous band, are continued from the sub-œsophageal ganglion along the middle of the under part of the abdomen, attached to the ventral integument, and inclosed, as it were, by the great ventral vein. Twenty-one equidistant rhomboidal ganglions are developed upon these chords, which distribute their filaments to the adjoining segments by two powerful diverging trunks on each side. The segments indicated by the external circular indentations of the integument, are much more numerous than the ganglions. Dr. Brandt has detected a simple nervous filament continued from the œsophageal ganglion along the dorsal aspect of the alimentary canal. This is an interesting structure, as being an early trace of a distinct system of nerves, usually called the stomato-gastric in Entomology, and to which our great sympathetic and nervus vagus seem answerable.

The structure of the abdominal ganglion in the *Articulata* was first illustrated by the microscope and pencil of Ehrenberg as it exists in the leech*; in the centre of the ganglion are several clavate corpuscles, the enlarged end of each being formed by a nucleated cell, the tapering extremity is continued into the diverging nervous chords: the clavate cells are arranged in eight groups, two groups being continued into each of the four diverging chords of the ganglion; a few filaments pass lengthwise through the ganglion, and are in more immediate communication with the cerebral one.†

In the earth-worm the super-œsophageal ganglion consists of two lateral lobes, which send off small nerves to the proboscis and the two large chords to the sub-œsophageal ganglion; some small filaments are derived from the œsophageal collar. The two ventral nervous trunks are more distinct from each other than in the leech; but the ganglions are relatively smaller and more numerous, corresponding in number with the segments of the body. Two pairs of nerves are given off from each ganglion, and a third pair comes off from the intermediate chords. The terminal or anal ganglion distributes a plexus of nerves to that termination of the body.

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* Poggendorf's Annalen, 1833, and CLXXXVI. p. 665, tab. vi. fig. 6. (1834.)

† The homologues of these are pointed out by Mr. Newport in the Lobster (CXCII. 1834, p. 406). Dr. Carpenter, in CXXXVIII. (1839), cites Dr. M. Hall as having "suggested that the ganglionic portion of the chord ministers to the reflex actions of the respective segments, whilst the white tract (continuous filaments in connection with the brain) conveys the motor influence of the cephalic ganglia" (p. 62). He adds, that it may also "convey sensory impressions to those ganglia" (ib.).

In the Nereis the abdominal ganglions are more distinctly bilobed than in the earth-worm, and the super-œsophageal ganglion is relatively larger, having to furnish nerves to both antennæ and ocelli; the latter projects as a black spot from the base of each of the two chief cephalic tentacles. The pairs of ganglions developed upon the ventral chord, correspond with the segments of the body in number, and are very close together. In the *Eunice gigantea* there are upwards of 1000 ganglia; but this complicated condition of the nervous system is more apparent than real, and, like the multiplication of the pulsatile sinuses of the vascular system in the same animal, depends upon the vegetative repetition of like parts, without any mutual subordination in reference to the performance of a special office.

In the Aphrodita the body is broader and thicker than in other Anellids, and begins to exhibit that concentration which characterises its form in the higher Articulata. But the segmental nervous ganglions, though more closely approximated, are yet not confluent at any central part. The brain is heart-shaped, having its bilobed base turned backwards, and connected in the usual manner by large œsophageal columns with the inferior ganglion. The antennal nerves are continued from the apex. The visceral nerves are given off from the œsophageal circle, and pass to the upper surface of the intestine, and there swell into a small ganglion. The sub-œsophageal ganglion is of large size, and bifurcates anteriorly: the second ganglion is situated close by the first, and gives off two pairs of nerves: the third to the fifteenth ganglions send off respectively three pairs of nerves, the first of which corresponds with the interganglionic nerve in the earth-worm, and supplies the branchial organs; the second pair is distributed to the ventral muscles; the third, to the lateral and dorsal muscles. The abdominal ganglions, which succeed the fifteenth, send off each two pairs of nerves, and gradually diminish and approximate at the posterior extremity of the body. In this highly organised anellid the nerves may be distributed into those of special sense (antennal), the sentio-volitional, the excito-motory, the sympathetic or stomato-gastric, and the respiratory. The leech is very susceptible of meteoric changes; and instruments have been constructed, of which a very ingenious one was shown in the "Great Exhibition of 1851," in order to make the characteristic movements of these Anellids subservient to the purposes of a barometer.

"Those who have watched the habits of the *Nereids* will scarcely doubt that they are gifted with the power of discriminating external objects, of making towards some point, and of avoiding others. In the absence of such an optical arrangement as may be fitted to collect the rays of light, the physiologist, however, can form no conception of the mechanism of sight in these animals, if this endowment really is conferred upon them, under the conditions and in conformity with the laws which affect these organs in all the higher animals. It were, however, by no means irreconcileable with the views entertained at present as probable by many philosophers with reference to the properties of light, to suppose that this subtile agent may be rendered perceptible to the sensorium of the humblest animals, by means of a mechanism very different from that which anatomists and opticians recognise in the apparatus of an eye. It is not essential to the practical purposes of the lowest forms of life, that the objects of the external world should be *seen*, that pictures of them should be painted upon the retina; it were enough that the mere presence or absence of an objective body should become evident to the sensations of the animal by the positiveness or negativeness of the impressions received. A refinedly exalted sense of touch, tactile sensibility, would suffice to accomplish this object. It is not easy for those who have never enjoyed the spectacle of the 'feat of touch,' performed by the tentaculated worms, to estimate adequately the extreme acuteness of the sensibility which resides at the extremities of the living threads with which the head and sides of the body are garnished. They select, reject, move towards and recede from minute external objects with all the precision of microscopic animals gifted with the surest eagle-sight. The necessity, therefore, of ordinary organs of sight, in the present state of physical and physiological science, it is by no means essential to admit, while acknowledging that under the agency and stimulus of light the humblest beings, though unendowed with normal visual organs, may yet steer themselves harmlessly, readily, and unerringly through the thickly tangled labyrinth of mud and stone, and gravel and weed, amid the twilight of which the habitat of many of them may have been cast.

"It is a remarkable fact in the history of the Anellids, that scarcely any species, however organised, whether furnished or not with external locomotive organs, in its numerous and varied muscular evolutions *ever moves directly backwards*. The movements consist always of serpentiform pranks, or those of elaborate coiling. It is by the head, however, that the movement is invariably initiated. The tail is always in the rear, never in the van." *

On the first appearance of the embryo anellid, it usually consists of a single segment, which is chiefly occupied by a large mass of unmeta-

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* CXC. p. 268.

morphosed germ-cells. And these are not used up, as in higher animals, in developing the tissues and organs of an undivided or individual whole; but, after a comparatively slight growth and change of the primary segment, proceed, in the typical orders, to form a second segment of somewhat simpler structure, and then repeat such formations, in a linear series, perhaps more than a hundred times. So that we may have a seeming individual anellid consisting of many hundred segments, in which a single segment would give all the characteristic organisation of such individual, except some slight additions or modifications characterising the first and last of the series. Thus the anellids are more simple in their structure than they appear at first sight, especially before arriving at full maturity, when in certain species, as the leech, nais, and earth-worm, particular segments are distinguished by the development therein of the special male and female generative organs. With this characteristic mode of growth by repetition of segments, we should be prepared to expect in these creatures great powers of repair after injuries and mutilations — powers which have been made the subject of many and ingenious experiments. In the works of Spalanzani and Bonnet more particularly are recorded the most striking results of such experiments. A worm cut in two was found to reproduce the tail at the cut extremity of the cephalic half, and to form a head upon the caudal moiety. Bonnet* progressively increased the number of sections in healthy individuals of a small worm or nais, which he calls the *Lumbricus variegatus;* and when one of these had been so divided into twenty-six parts, almost all of them reproduced the head and tail, and became so many distinct individuals. Sir John G. Dalyell has succeeded in artificially propagating a *Sabella* in the same way. The small fresh-water naids show great powers of repair and reproduction; these little worms have a paler colour of the blood than in most *Annulata;* but through the transparent skin you may clearly see its circulation. There are some species found in sand or mud, such as those that stain of a red colour extensive tracts of the Thames mud at low water, which, when submerged, habitually protrude the anterior half of their body, which is remarkable for its regular oscillating movement. Bonnet cut off the head of one of the naids of this genus, which was soon reproduced; and, when perfect, he repeated the act; and again as often as the head was reproduced. After the eighth decapitation the unhappy subject was released by death; the execution took effect, the reproductive virtue had been worn out. This series of experiments occupied the Genevese philosopher two summer months. Since many of the smaller kinds of naids frequently expose a part of their body, the rest being buried in the earth, both they and their enemies profit by the power of restoration of the parts which may be bitten off.

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* CLXXXII. pp. 117. 245.

With this power of reproduction of lost extremities is associated that of spontaneous propagation by developing and detaching new series of segments.

Spontaneous fission has now been observed to take place in almost every order of *Annulata;* and in all it takes place at nearly the same part, near the beginning of the posterior third part of the body; but, the formation of the new anellid is due to a process of gemmation of new segments, which proceeds from the last or penultimate joint. It is most common, or has been oftenest witnessed, in the little abranchial fresh water naids. But Otho Frederic Müller has represented a young *Syllis* (his *Nereis prolifera*) in the act, in his great work, the "Zoologia Danica." Gruithuisen has described the process in a *Chætogaster;* Oersted, in an *Eosoloma;* M. Edwards, in a *Myrianes* (Nereis); and Schmidt in a tubicular anellid, called *Filograna Schleideni.*[*]

The place where the process of forming the new segments is to be carried on, is soon indicated by a slight swelling and increased vascular action. If the head or anterior segment of the species be characterised by eye-specks, antennæ, a proboscis, or branchiæ, these are developed in a certain and always recognisable degree, before the final separation takes place. In the *Myrianes,* the coloured eyes indicate the young fry. In the cephalobranchiate anellid, the gills are shown, in the stage of fission represented by Professor Schmidt, as four pairs of articulated filamentary vascular processes. In the *Nais proboscidia,* the characteristic proboscis shoots out from the nascent head of the young worm, which is thus duly armed before it is cast off to provide its own nutriment. The last joint of the young naid is specially ciliated, like that of the mother; and the corresponding portion of the alimentary canal has thick walls, with numerous filamentary or vascular appendages. This gemmiparous segment resumes its procreative function in the parent as soon as the lineaments of the head of the first young nais are established; and a second young nais, with a rudimental proboscis, intervenes between the first and the original parent; sometimes even a third nais is indicated by the elongation, swelling, and active vascularity of the last joint; and thus four generations of naids may be seen organically

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[*] The ill success of a later experimenter does not justify the contemptuous tone in which the results of his, perhaps more skilful and careful, predecessors, are rejected. See CXC. passim.

connected and constituting one individual. Such individual is due to the succession of incomplete gemmations; the reproductive process is completed, and the compound animal is resolved into the single individuals, by spontaneous fission. The nucleated cells that are aggregated in the penultimate or proligerous segment, form a significant feature in its organisation. As long as the anellids propagate by this primitive mode, they manifest no ovaria or testes. These are developed in those individuals which are propagated by gemmation and spontaneous fission, when the proper season for oviparous generation has arrived. M. Edwards observed, that a nereis allied to *Myrianes* generated in succession six young from the same posterior segment, each of which developed the true generative organs, without the parent itself showing any trace of them. M. Quatrefages has noticed the same fact in a species of *Syllis*.

In many of the Anellids, therefore, the phenomena of parthenogenesis are manifested in the immature state; and, since the individuals so propagated alone acquire the generative organs, an alternation of generations may here be affirmed of such species: the oviparous individuals producing eggs from which the gemmiparous individuals come, and these, in their turn, reproducing the oviparous individuals.

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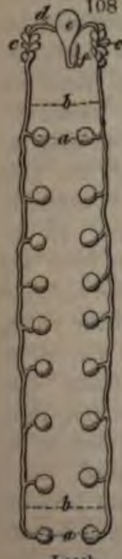

Leech.

I next proceed to point out the chief modifications of the generative organs properly so called. And first, as to the generative organs of the leech. In the medicinal species (*Hirudo* or *Sanguisuga medicinalis*) may be seen a number of pairs of little gray rounded bodies, usually nine pairs, which are the testes, *fig.* 108., *a a*; these are round whitish sacs, containing a milky fluid, abounding in spherical sperm-cells. A little duct proceeds from each to a common longitudinal vas deferens (*b*), near the anterior fourth of the leech, which forms a sacculated vesicula seminalis (*c c*), each of which sends its duct to a common small pyriform prostatic gland (*e*), from which is prolonged a filiform intromittent organ (*f*), which projects from the ventral surface of the twenty-fourth ring. But the leech is androgynous, and the female organs are situated behind this prostate and penis, between the seventh and eighth abdominal ganglia; they consist of two subspherical ovaria (*a*), two short oviducts (*b*), which unite to form a single oviduct (*c*) that expands into a pyriform muscular uterus (*d*).

Brandt and Ratzeburg * found in the bodies which they, with preceding anatomists, call the ovaries, roundish corpuscles with a reticulate surface, presenting in that structure an unmistakable resemblance to the parts regarded by Weber as the ova of the medicinal leech, and by Wagner as those of the *H. vulgaris.*

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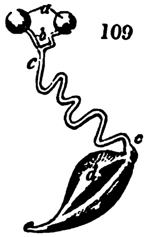
* CLXXXV.

The uterus, *d*, has a glandular lining membrane, a muscular tunic of longitudinal and transverse fibres, and a cellular outer coat. It opens by a short duct, or vagina, on the twenty-ninth ring. It contains a collection of eggs, with chorion. Brandt remarked, in a much distended uterus, although the major part of its contents had been already evacuated, a delicate membrane like the chorion of an ovum, in which were many small yellowish corpuscles, very like the above described ova, which led him to suppose that that delicate membrane was the already developed innermost cocoon-skin.



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Leech.

In the naids the orifices of the male and female organs are in two pairs, situated about the anterior third of the body. In the *Nais proboscidia* the ovarium is included by the substance of the testis. Two cæca extend inwards, at the breeding season, from the two anterior generative pores, which are then found filled with spermatozoa grouped into fasciculi, and probably received from another individual *in coïtu.* The ova are carried out by long convoluted oviducts.

In the earth-worm the external characters of the generative organs may be clearly seen in Hunter's dissections. We perceive here, that the generative apparatus is more concentrated in the earth-worm than in the leech, and more individualised than in any other animal of the anellidous class. The three pairs of small opaque organs, which Hunter regarded as testes, may possibly be only "spermathecæ," like the anterior pair in the naids. They are laden with spermatoza during the breeding-time. The germinal vesicles and developing ova are found in the larger gray-coloured cæca; each of which sends out a distinct short oviduct, and these combine into a common oviduct on each side, opening behind the orifices leading from the testes or spermathecæ. If a section of one of these ovarian sacs is made, it is found filled with a spongy matter in the centre, and the ova are situated in this. The common oviduct from each lateral series of ovaria terminates in the fissure upon the sixteenth segment, about one-third from the head. It is interesting to note here, that the condition and function of the oviduct in the earth-worm is analogous to the arrangement of the generative parts in plants. In plants, the part answering to the oviduct is a distinct canal, communicating with the pistil, and serving to convey the pollen to the ova; but the ova afterwards escape by rupture of the ovarium, or by what the botanist calls dehiscence of the seed-capsule. It is exactly so with the earth-worm; the so-called oviducts serve to convey the impregnating principle to the ova, which escape into the abdominal cavity of the earth-worm, by bursting through the ovarian sacs. In these sacs, however, there is always found a quantity of spermatozoa in different stages of development; and accordingly the generative organs of the earth-worm are open to two interpretations. The anterior organs may be regarded, as by Hunter and Cuvier, as the testes, or they may answer only to the spermatheca in insects; and, in that case, the true male organ may be that external spongy part which surrounds the proper ovarium; and this would not be a solitary instance of such an arrangement of the essential organs of generation in the animal kingdom, but one which is very common in the androgynous gasteropods. However, there is much room for research and experiment to clear up this difficult moot-point.

Both the leech and the earth-worm enjoy a double or reciprocal coïtus; the leech has a true perforated intromittent organ; the earth-worm has not. During the breeding season, however, two imperforate appendages are developed from about the thirty-second ring; their base adheres intimately to the cellular tissue; they have no communication with the genital apertures; are developed only at the breeding season; and are deciduous. The second accessory organ is that thickened part of an earth-worm which is situated between the thirtieth and the fortieth segments; it is called the "clitellum," and, when two earth-worms are disturbed *in coïtu*, the adhering clitella are the last parts to give way.

With regard to the dorsibranchiate and tubicolar Anellides, many of these are diœcious. The sperm-sacs or testes are situated on the ventral aspect, between the layers of the ventral muscles. The development of the ova is more clear and obvious; because they are commonly remarkable for the bright colour of their vitelline mass; and the number of ova is so great, that the ordinary colour of the anellid is changed at the breeding season. Thus, in the *Aphrodite cirrata*, Sars found that, in February, the three posterior fourths of the body were of a brilliant red colour, on account of the great number of ova there accumulated. Neither testes nor ovaria have external ducts; the products of both are discharged by dehiscence, into the abdominal cavity, and are excluded by pores situated near the base of the setigerous feet. In the Aphrodite, the ova pass between the dorsal scales, and there development takes place. There is but one known genus of anellid that exhibits external sexual characters, viz., the

Exogone or *Cystonereis.* In the females the middle segments exhibit pyriform sacs, attached to their ventral surface, which receive the ova after they are impregnated; the male is without these and is smaller. The genus *Eunice* is viviparous, and the young escape from the ruptured skin of the hinder segments.

Finally there remains to be considered the development of the generative products. As to the spermatozoa, these are formed in a number of cells connected together by a spherical mass, and studding its surface. (*Fig.* 110, A.) Each cell is the seat of development of a separate spermatozoon, and this in its growth pushes the cell-wall outward: the filamentary extremities diverge from the common basis of the sperm-cells (C); then, by mutual attraction, they become amassed together (D); and the bundle is finally resolved into the individual spermatozoa (B).

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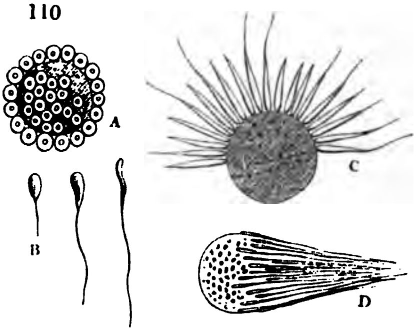

Sperm-cells and spermatozoa, *Lumbricus*.

Dr. A. Farre has communicated to me the following phenomena which he witnessed during microscopical observations of the spermatozoa of the earthworm. He placed the contents of the testis between two slips of glass. " In about ten minutes the whole mass is seen to heave and writhe with astonishing energy, the form of the movement being that of the peristaltic action of the intestines. Everything in contact with the spermatozoa becomes ciliated by them, one end of the filaments fixing itself whilst the other vibrates free. The result is, that if the body to which the spermatozoa attach themselves is fixed, such as the glass, on the margin of a mass of granules, a line of cilia is formed, whose action creates a strong current, and everything moveable is drawn into the vortex, and is seen drifting rapidly along. But if the body to which they attach themselves is moveable, such as the globular bodies found in the testis itself, or those which occur in every part of the ovary, and which, being extracted from the latter, are placed, for the sake of experiment, amongst the spermatozoa from the testis, then the globular bodies soon become clothed with spermatozoa, whose free ends, moving rapidly, cause the whole body to rotate. A most remarkable object is thus formed, which continues for a considerable time in motion, clearing for itself a free area, and in this it revolves, whilst its revolutions are apparently assisted by the action of other spermatozoa, which, having attached themselves to the periphery of the cleared space, keep up a complete vortex, in which the centre body is partly a passive and partly an active agent. This remarkable property of spermatozoa, in performing the office of cilia, is, as far as I am aware, a new fact, and one which may serve to explain possibly the transference of the sperm fluid, or even of ova, of various animals, along surfaces or tubes not naturally ciliated."*

In regard to the development of the ova and embryo in the earthworm, the ova, when they are impregnated, are discharged from the ovarium, pass into the abdominal cavity, and are pressed on to a receptacle near the anal end of the worm. Dr. A. Farre has traced the development in some instances, which is so far analogous to that of the Ascaris, that the embryo acquires the worm-like form before it leaves the egg. It appears that some earth-worms are developed before they are excluded, but this is not always the case. The whole of the process, however, is complicated and obscured by a considerable number of parasites, eggs of gregarinæ and pseudo-navicellar capsules, so that it is one of the most perplexing fields of microscopic observation.

The generative phenomena of the leech are less dubious. Mr. Quekett and others have found that the spermatozoa are developed in the testes, *a*, *fig.* 108., in the same manner as in the earth-worm and other Anellids. The ova of the leech are spherical, and exhibit, when found in the ovaria, *a*, *fig.* 109., and oviducts, the usual constituents of ova. There is a germ-yolk with a germinal vesicle and spot, and a delicate vitelline membrane. When the ova are received into the uterus, the germinal spot has disappeared, intimating that impregnation has taken place, and a delicate reticulate chorion is acquired.

The medicinal leech is oviparous; the fertile ova are successively discharged in groups of from six to fourteen, enveloped in a nidus or cocoon of mucus. The cocoon is ovate, two-thirds of an inch in length, and half an inch in diameter. It has a flocculent outer surface, but is smooth and slightly tuberculate within; a more conspicuous, though minute albuminous plug, projects inwards from each pole of the cocoon. In the month of August, conical excavations may be observed in the slime at the sides of the reservoir, in each of which there is a cocoon. The formation of the cocoon is the result of a curious manœuvre. In the *Hirudo vulgaris*, when the cocoon is about to be formed, the body is observed to be greatly contracted, both above and below the uterus; the included part swells, then becomes milky white, from the formation of a film, into which the animal, having attached itself by its anal sucker, forces, after some effort, the whole contents of the uterus. This being done, the leech elongates the anterior part of its body, and, thus loosening the enveloping membrane, withdraws its head as from a collar. It sometimes bends back its head, and, drawing the collar forwards, gently aids in its removal. The process usually occupies about twenty minutes. The cocoon is at first very elastic, and has no determinate figure. After the leech has attached to it some adjoining substance, it fashions it with its mouth into an oval form. The points of the cocoon from which the leech withdrew its head are weaker than the rest, and from these the young escape.

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* CXCVI.

Mr. Brightwell, who has carefully observed this common species of our freshwater pools, states:—"On the 2nd of June, *H. vulgaris* deposited one capsule containing ova; on the 5th, another; on the 10th, another; and on the 15th, two more; each of them containing from seven to ten eggs. On the 22nd, the young appeared in the capsule deposited on the 2nd; and on the 13th of July they emerged from the capsule, and in six weeks were fully developed, and left the capsule. Examining the young of this species with a power of about sixty linear, we detected a Cypris and four specimens of a common rotiferous animalcule in its stomach, one of the Rotifera being still alive."*

Both Weber† and Filippi‡ have figured ova of the leech-tribe in certain stages of cleavage; but the primary and subsequent steps of this important process in anellidous ova were first noticed by Kolliker§ in a small Nereis (*Exogone Orstédii*), with the impregnated ova contained in marsupial sacculi arranged in two rows along the ventral side of the body; each sacculus held a single ovum, and was suspended, a pair to each segment from the tenth to the twenty-third inclusive, by a short stem to the ventral integument. These sacculi are probably formed by albuminous mucus, exuded and hardened by sea-water. Kolliker figures the single central germ-cell; the double germ-cell, followed by the total fission of the yolk with the secondary germ-cell in each; these cells again divided, and the consequent quadrifid division of the yolk; followed by successive subdivisions, as in the Ascaris.

In the egg of *Clepsine*‖, after the disappearance of the germinal vesicle a whitish discoid mass of molecular corpuscles appears at one end of the yolk. Assuming this to mark the pole, the first line of cleavage is a meridional one, which bisects the disk unequally:

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* CXCVII. † CXCV. ‡ CXCVIII. § CC. ‖ CCV.

a second, third, and fourth meridional cleft succeed each other, and then the yolk is further subdivided by an equatorial cleft into nine yolklets, the ninth occupying the opposite pole; the process continues until the yolk is well subdivided: when the germ-rudiment appears at the germinal pole, it consists of parietal granules, spread out into a layer which progressively expands to cover the germ-cells. The influence of the primary germ-cells operates more partially or locally upon the yolk-mass than in the Nereids; and, although the spontaneous fission of the germ-cells is accompanied by total cleavage of the yolk in all Anellids, that process is less regular in the aberrant *Suctoria* than the typical orders of the class.

The best account of the development of the medicinal leech is given by Dr. E. H. Weber*, whose illustrations are copied by Brandt and Ratzeburg.† The egg-mass in the uterus is cylindrical, brownish, and subtransparent: it is extruded with difficulty, and can hardly be taken from the cavity uninjured. When the mass has been four hours in water, it assumes a longish oval form. Some of the stages of the cleavage of the yolk have been observed in eggs in the cocoon; two of these appear to be figured by Weber.‡ When the yolk has undergone its subdivision, and its peripheral stratum has been metamorphosed into the primitive germ-layer, a large clear space or cell appears in the centre, from which an infundibular canal extends to, and opens upon, a part of the periphery, covered by a ciliated epithelium; the sucker, which afterwards forms the mouth, is here developed, and is the first recognisable part of the future leech. The mouth, when the embryo is little more than a line in length, dilates and contracts, and some fine lines radiating from it already indicate the muscles subservient to the act of nutrition, which consists in the embryo's swallowing the surrounding albumen. The integument extends in a straight line from the mouth, along a narrow median tract of the ventral surface of the germ-mass, to about one-third from the opposite end; and when the embryo is three lines in length, if it be placed in alcohol, and afterwards in water to restore the translucency of the gelatinous parts, the ganglionic chain may be traced along the median line of this part of the integument. When the ganglions are visible without chemical preparation, the mucous loops begin to appear as whitish transverse streaks. Next, the anal sucker is developed, and the cephalic end of the embryo begins to stretch forth from the yolk or germ-mass. The testes, with their common sperm-duct on each side, and the ovaria and uterus, are now discernible; but they are proportionally, especially the testes, more minute than the mucous loops and round mucous sacs, whose development keeps pace with that of the general integument. The circulation can be discerned before the pigment-cells are formed in the skin; and the large lateral veins are early conspicuous. The superficial cilia disappear; and the embryo, which hitherto, by its vibratile surface and single opening of the digestive cavity, has resembled a planaria, now acquires an anus. The yolk-mass is progressively pushed by the growth of the integument to the dorsal and anal parts of the body, the last remnant appearing as a conical papilla above the anal sucker. The internal yolk-mass is divided by the growing septa or constrictions of the stomach, the intervening dilatations of which are afterwards developed into sacculi, and of these the last pair is already the largest; the remainder of the yolk is inclosed by the intestine, whose outlet surrounds the external projecting part. The alimentary canal contracts and expands on the contained yolk-material. This course of development extends over six weeks. Weber traced it from the 6th of July to near the end of August. At this time, the young move about in the cocoon, which may contain from five to fifteen; the comparative paucity of the young, even when a vigorous leech successively forms and fills as many as six cocoons, agreeing with the small size and number of the ovaria. They escape by perforating one end of the cocoon, and are subtransparent, but show as many rings as the parent. But little growth takes place up to the month of December: the young get sustenance by sucking the mucus of the parents, but will grow, if isolated, by assimilating the remnant of the yolk-mass in the stomach. The period of acquiring the full growth and power of propagation depends much on the opportunities the young leech may have of sucking the blood of other animals. Johnson believes that five years elapse before the medicinal leech is full-grown, and speaks of one which he kept alive twenty years. De Blainville found two-year-old leeches only three inches long. Audouin could not succeed in keeping them beyond from eight to twelve years, when they were allowed to propagate. The *Naides* and *Arenicolæ*, according to the author of the "Report,"* are annuals. "They are born during the latter months of one summer, and survive the winter, attain to the maturity of growth, reproduce the species, and die by the spontaneous subdivision of the body into fragments on the arrival of the same season of the succeeding year."

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* CXCV. pp. 127—197.

† CLXXXVII. taf. xxx.

‡ Op. cit. t. x. figs. 2 and 3.

Koch† found a specimen of *Eunice*, probably *E. sanguinea*, with developed embryos in most of the joints; some of the hindmost seg-

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* CXC. † CCVII.

ments seemed to have been spontaneously cast off, and the embryos escaped from the ruptured surface. Those at the lowest observed stage of development presented a roundish or oblong form with eeble lateral indentations indicating two or three segments, a wide entary canal filled with the yolk-mass, and no trace of antennæ, eye-specks, or jaws. When the embryo has attained one line ngth, the segments are defined and increased in number to twenty or thirty; on the anterior half of these, commencing with the third segment, the conical bases of the setigerous feet are developed; the segments appear to be increased in number by successive divisions of the second; a pair of eye-specks and jaws are next developed; and the segments, being multiplied and provided with single-bristled feet, the young Eunice presents the characters of a *Lumbrinereis* of Audouin and Edwards.

In most branchiated anellids the embryo is excluded as a ciliated eroidal animalcule. It lengthens, partially casts its cilia, retaining them arranged either in a cincture round the middle of the body, or in two bands one about each extremity. At the anterior end the eyes eye-specks appear; the segments are indicated on the rest of the dy, and the tubular feet and their bristles sprout forth; the little anellid afterwards taking on the modifications which distinguish its family, its genus, and, finally, its species.

In the development of the typical Anellids, there is something, therefore, which merits the name of a metamorphosis. Professor Lovén, for example, captured, in August, on the shores of the Baltic Sea, a discoid animalcule (*fig.* 111), which rapidly moved by means of two rows of vibratile cilia: the principal row being situated upon a projecting ring (*b*), at the margin of the disk. This ciliated body differed from the gemmules of the Polypi, in being provided with a mouth (*e*) and an anus (*c*), the latter occupying the apex of the cone. The course of the alimentary canal, which extended from one to the other aperture, was detected by feeding the little animal with indigo. In a short time the cone began to elongate and to be divided into segments, which were developed in four parts, the two principal pieces forming half-rings, one upon the upper, the other upon the lower surface, which were united by two shorter side-pieces. Coincident with the elongation and segmentation of the body, was the development of the head from the discoid surface (*a*), upon which first the black ocelli, and then two pointed filaments, or antennæ (*f*), made their appearance. The

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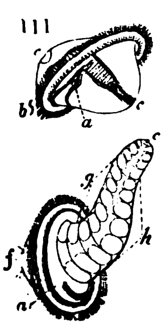

Embryo of Nereis.

length of the body, and the number of segments, continued to increase, the disk with its vibrating cilia (*b*) still existing. This disk is afterwards reduced to an appendage on each side of the head, and finally disappears. The new rings are added in front of, and not behind, the older ones, agreeably with the order of development of the segments in the *Bothriocephali*, described in a former lecture. Each ring originally consists of an upper (*g*) and an under half-ring (*h*), analogous to the tergum and sternum in the external skeletons of insects. The tubular and setigerous feet are lastly developed from the small lateral pieces. These observations beautifully exemplify the repetition of structures and phenomena, characteristic of mature animals widely separated in the natural scale, in the immature states of an intermediate species.

With regard to the genus *Aphrodite*, Sars * took a small species, in the month of February, on the Norwegian coast, which produced richly-coloured ova, and he traced the successive development of these. He found that the ova escaped from small pores, and were received into a kind of pouch beneath the dorsal scales, and there underwent their development and escaped. He observed the geometrical division of the rose-coloured yolk, and the clear spot in the centre of each successive division. The embryo is an active locomotive oval mass, with a little group of cilia, and an indication of an eye-speck to guide its course; after swimming freely for twenty-four hours the development of segments commenced. In the *Cystonereis*, in which the ova are incubated in marsupial sacs, the development of the animal appears, as in Koch's *Eunice*, to take place without that amount of metamorphosis which has been observed in other *Errantia*. First, there are two short tentacula, then three; then the animal elongates, and before it quits the marsupium, it presents a recognizable miniature of the parent.

Observations have been made on the development of the tubicolar anellids by Milne Edwards.† He found a group of ferruginous yellow ova, aggregated in a gelatinous mass, at the entry of the tube of the *Terebella nebulosa*. The embryo, when excluded, is monadiform, and swims by the vigorous vibrations of its superficial cilia; it lengthens, and the cilia, which at first were generally diffused, become confined to a cincture behind the head, a transverse ventral band near the tail, and a small circle round that part. The head is distinguished by two red eye-specks; new segments are successively added, one behind the other, and always in front of the anal one; but as yet the embryo is apodal. The tubercles and setæ are next developed in the same order, and a free-moving or "errant" anellid ensues. Finally, the cilia of the buccal rings are lost, the young Terebella reposes, and envelopes itself in a mucous tube. It is now half an inch in length, and the circulation may be seen in the dorsal vessel, the branchial filaments, and the cephalic antennæ.

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* CCII. † CCVI.

Thus, in the class *Annulata*, the observations on development, so far as they have extended, show that its progress varies in different orders, and in a minor degree in different families. The embryo of the leech, as soon as it is individualised, or made distinct from the germ-mass, presents the characteristic forms and locomotive organs of the parent: it indicates, only in a very transient way, during the development of this form, some characteristics of the *Turbellaria*. In the earth-worm the ultimate form is obtained by a successive development of segments, without any previous free locomotion of the embryo as a ciliated monad. The embryos in some viviparous Errantia, e. g. *Eunice* and *Cystonereis*, are at first acephalous, apodal, and abranchial, but do not manifest a rotifer-like stage. The young of other dorsibranchiate and of some cephalobranchiate anellids, on the contrary, start into free locomotive life under a form, and with instruments and modes of locomotion, quite distinct from those that characterise the adult. We may hence deduce the necessity for caution in generalising as to the metamorphosis or non-metamorphosis of a particular class. A very interesting phenomenon in the development of some of the *Errantia* is that which has been noticed in the young of certain species when it has acquired the form of the parent: its manifestation, viz., of a power of parthenogenetic propagation by virtue of the retention of unchanged germ-cells or nuclei in the penultimate and last segments of the body: it would seem, moreover, that it did not develope male or female organs in its own person, but that these are formed in the offspring propagated by gemmation and spontaneous fission. Should these observations receive confirmation and extension, they will show that such *Annulata* are subject to what has been called "alternate generation," although somewhat modified as compared with that which has been noticed in the *Entozoa* and *Acalephæ*.

CLASS ANNULATA.

Body soft, symmetrical, vermiform, annulated; with suckers, setæ or setigerous tube-feet. Alimentary canal with two apertures and proper parietes. A vascular system circulating, in most, red blood: respiratory organs. Ganglionic double nervous chord.

Order SUCTORIA (Leeches).

Body, terminated by a sucker at each extremity, without setæ or tubular feet. Alimentary canal adherent to the integument. Androgynous and ametabolian.

Genera *Branchiobdella*, *Piscicola*, *Clepsine*, *Nephelis*, *Hoemopis*, *Sanguisuga*, *Pontobdella*. (This aberrant order leads, by the Nemertine worms, to the *Turbellaria*.)

Order TERRICOLA (Earthworms, Naiads).

Body, long, cylindrical, the rings provided with setæ. Alimentary canal closely attached by numerous bands to the abdominal walls. Androgynous.

Genera *Chætogaster*, *Enchytræus*, *Nais*, *Lumbriculus*, *Euaxes*, *Sænuris*, *Lumbricus*, *Sternaspis*.

Order ERRANTIA (Nereids, Sea-centipedes, Lug-worms, and Sea-mice).

Body-rings with tubular setigerous feet; external gills on the greater number. Alimentary canal loosely attached to the abdominal walls. Diœcious. Metabolian.

Genera *Arenicola*, *Ammotrypane*, *Chætopterus*, *Aricia*, *Aricinella*, *Cirratulus*, *Ophelia*, *Peripatus*, *Glycera*, *Nephthys*, *Alciopa*, *Syllis*, *Phyllodoce*, *Hesione*, *Lycastris*, *Nereis*, *Oenone*, *Aglaura*, *Lumbrinereis*, *Eunice*, *Amphinome*, *Sigalion*, *Polynoë*, *Aphrodite*.

Order TUBICOLA (Animal-flowers).

Body-rings with tubular setigerous feet; gills attached to or near the head. Alimentary canal loosely connected with the abdominal walls. Diœcious. Metabolian.* Inhabiting natural or artificial tubes.

Genera *Serpula*, *Sabella*, *Amphitrite*, *Terebella*, *Amphicora*, *Chlorœma*.

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* The *Sabellina brachycera*, Dujardin (Annales des Sciences Nat. t. xi. 1839, p. 291, pl. 7. f. 6.), and the *Anisomeleus luteus*, Templeton (Trans. Zool. Soc. t. ii. pl. v. figs. 9—14.), are probably larvæ of Tubicolar anellids.

LECTURE XIII.

EPIZOA AND CIRRIPEDIA.

The phenomena of the generation and development of the animal kingdom, so far as we have traced them, must, already, have impressed us with the inadequacy of the knowledge of the nature of an animal in its final and complete stage of existence only, for the determination of its affinities and proper place in the natural system. This we have learnt from a study of most of the previous classes of animals; it is more plainly demonstrated by the subjects of this day's discourse. I may also here observe, that whilst it is essential to trace the metamorphoses of each species in order to rightly comprehend its true nature, the study of the generative organs shows that we cannot rely on them alone for a system of classification. We saw, for example, that some of the anellids combined both male and female organs in the same individual, while others had those organs separate and peculiar to distinct individuals; one order was androgynous, another diœcious. In the earth-worm we had evidence of a certain concentration of the generative system within a few segments; in the leech, of a sub-division and more extended placing of the male organs: but this vegetative character was most remarkable in the diœcious anellids, in which almost every joint presented either its pair of testes or of ovaria, according to the sex of the individual. Then, in reference to the progress of development of these worms, some transitorily manifested the form and character of one class, inferior to them in the animal scale, and others those of another lower class; thus the embryo leech represents the planaria, whilst most of the higher anellids quit the ovum in the infusorial form. The further progress of development was interesting, since it reminded us of that singular propagation of certain Acalephæ, in which the larva produced other larvæ like itself, before it was metamorphosed into the final form of a medusa. For the ordinary mode of growth of the Anellid, by the development of joint after joint, one precisely similar to the other, throughout a series of, perhaps, hundreds of joints, with only the first and the last segments distinguished by any peculiar characteristics,—all this process of growth looked very like an incomplete parthenogenesis; but this mode of production is fully manifested by the successive casting off of groups of segments, with the characteristic head and tail, as in the instances cited in the preceding Lecture; the young anellid from the ovum propagating at first by gemmation and spontaneous fission; and the individuals so produced developing the ordinary organs of generation.

The low organised articulated classes, which succeed the Anellids in the rising progress, undergo such extraordinary metamorphoses before attaining their mature state, as to mask their true relations, not only to the class, but to the primary division of animals to which they belong. This is especially the case with the creatures whose organisation and development will form the subject of the present Lecture.

This elongated, cylindrical, unarticulated Lernæa (*fig.* 112), whose smooth soft body seems devoid of any other appendages than the two long slender ovisacs (*f*), might be regarded, on the fall of these deciduous appendages, as one of the entozoa of the fish to which it is attached, and on the nutrient juices of which it subsists.

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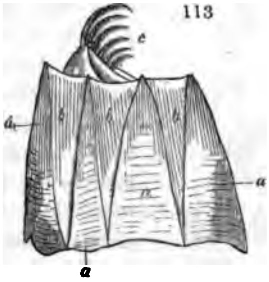
Peniculus fistula.

113



Balanus sulcatus.

This Ballanid (*fig.* 113), imprisoned in its conical calcareous shell, and cemented to the stone on which it grew, might seem as naturally to belong, like its neighbour the limpet, to the testaceous Mollusca.

How minute and accurate must have been the investigation of the forms and structures of these animals, at every stage of their existence, before the truth began to dawn, that they were more nearly allied to one another than to any other class of animals! The most vivid imagination of the boldest generaliser or speculator upon the unity of organisation in the Animal Kingdom could never have divined that the Lernæa and the Cirriped were at one period of their lives locomotive animals, swimming about under very similar forms, and by almost identical natatory instruments,—not under the common ciliated infusorial form, in which the Polype, Acalephe, Echinoderm and certain Entozoa, Anellids, and Mollusks, first enter into active life,—but with symmetrical pairs of jointed setigerous legs like those of the full-grown errant Anellids and the lower organised Crustaceans, to which the *Epizoa* and *Cirripedia* are, in fact, essentially and most closely allied, although they end their career as sedentary animals under such different, such diversified, and, often, such grotesque forms.

These metamorphoses, moreover, lead to very different results, as respects the powers of their subjects, from those of the Medusa and Comatula. The Epizoa and Cirripeds acquire increase of bulk and organs of generation; but, in every other respect, the varied course of their development ends in a retrograde movement.* Their development would seem to have been at first, as it were, hurried forward at too rapid a pace, and the young parasite, starting briskly into life, ranging to and fro by the highest developed natatory organs we have yet met with, and guiding its course by visual organs, must lose its eyes and limbs before it can fulfil the destined purpose of its creation.

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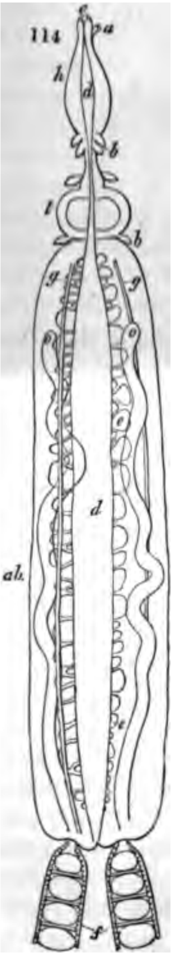

Peniculus.

The *Epizoa*, by which name we recognise the singular class of animals which infest the skin, the eyes, and the gills of fishes and other marine animals, — these external parasites, which are as numerous as, and perhaps more numerous than, the whole class of fishes, — are distinguished in their mature state by a body of a more or less elongated or sub-cylindrical form, defended by a smooth, semi-transparent, parchment-like integument, having a more or less distinct head, and generally a pair of long cylindrical ovisacs† (*figs.* 112, 114, *f*), dependent from the opposite extremity of the body.

In this low organised class of Articulate animals, as in the classes which commence all other great primary groups, there is an extensive gradation of forms by which we pass from species slightly elevated above the cavitary Entozoa to the true Crustaceans.

The lowest and most simple Epizoa adhere by a suctorious mouth (*fig.* 114, *a*), and traces of extremities exist only in the form of a few minute pairs of obtuse inarticulate processes (*b*). In the higher organised species, the adhesion is effected by suctorial (*fig.* 116, *m*) or prehensile limbs, or by jointed mandibles, with terminal hooks or forceps (*fig.* 115, *b*). The head, in most of the species, is found, when closely examined, to present a pair of jointed antennæ (*figs.* 115, *f*, 117, *c*), which, contemplated by the experienced naturalist, cognisant of the value of such characters, might excite the suspicion that relations to higher *Articulata* than the Anellids were hidden under the bloated form which indolent and gluttonous habits had superinduced upon the pendent parasite. Observation of it during its early and locomotive state has proved this to be actually the case to an extent which could not have been anticipated.

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* LXXXIV. p. 155. (1843.) "Il faut donc distinguer avec soin les formes zoologiques qui peuvent être assimilées à celles qui produirait un arrêt de développement chez d'autres animaux de la même série, et celles qui resultent d'un développement recurrent." — Milne Edwards, "Annales des Sciences." Feb. 1844, p. 77.

† By these appendages the Epizoa are distinguished from those highly-organized Entozoa — the *Linguatulæ*, e. g., — which by the inferior size of the male, the complex structure of the female, the two pairs of articulated and uncinated limbs of the larva, and the grade of development of the nervous system, seem to make the nearest approach to the present group.

The Epizoa are of distinct sexes: the male (*fig.* 117) appears always to retain his freedom, and is, perhaps on that account, singularly smaller than the female, generally not more than a fifth part of her size; consequently, for a long time, the males escaped recognition. They adhere to the vulva of the other sex with one antenna usually inserted therein. The female individuals, distinguished throughout a great part of the year by their pendant ovisacs, are the examples usually seen of this curious class; and in these I shall proceed to describe the anatomical characters of the Epizoa.

The body, independently of the ovisacs, is generally divided into two segments: the anterior and smaller division sometimes supports a distinct head, but more commonly corresponds with the cephalothorax of the Crustacea: the larger segment is called the abdomen, and in it the ovaria are developed. You will not unfrequently find adhering to the eye of the sprat an Epizoon or Lernæa*, which is a nearly allied species of the same genus (*Peniculus*) as the specimen figured and described by Nordmann (*fig.* 112)†, which infests the boar-fish (*Zeus aper*). In the *Peniculus fistula*, the head (*fig.* 114, *h*), is oval and notched anteriorly, each division being armed with an inwardly bent hook, or rudimental jaw (*c*). The mouth (*a*) is immediately beneath these, in the form of a circular orifice, supported by a short cartilaginous tube. At the posterior contracted part of the head are two pairs of short, oval, flattened processes (*b*): a constriction or neck separates them from the thorax, at the commencement of which there is a third pair of similar rudiments of locomotive appendages. The thorax (*t*) is round, and separated by a constriction from the abdomen (*a b*), a fourth pair of appendages (*b*) being developed from the interspace. The basis of the smooth parchment-like integument is chitine. The alimentary canal (*d*) is much

* CCVIII.

† LXXI. Heft. ii.

contracted in the neck and thorax, but expands in the abdomen into a moderately wide and uniform intestine, which again slightly contracts to terminate by a distinct anus at the hinder extremity. The alimentary canal has the same simple straight course in other species of Epizoa. One cannot be surprised at this correspondence with its general condition in the cavitary Entozoa, when the similarity of their easily assimilable nutriment is remembered. The intestine is, however, complicated in the Epizoa with a conglomerate or minutely-lobed adipose mass, which surrounds, like a net-work, nearly the whole extent of the abdominal tract of the intestine in *Lernæa*, *Lerneocera*, and *Lamproglena*, and which Nordmann supposed, from its gland-like character, might fulfil the function of a liver.

In some species which attach themselves to the gills and the like favourable positions for an abundant supply of the most nutritious fluid, the body is frequently deformed, as it were, by excessive growth, and cæcal productions from the simple straight intestine are continued into the prolongations of the thoracic or abdominal walls. The Nicothoë, a small parasite of the gills of the lobster, is an example of this condition of the digestive organ. The first segment of the body is produced into two lateral symmetrical wing-shaped lobes, each four times the length of the segment to which they are attached, and they contain corresponding cæcal prolongations of the straight intestine.*

In the *Peniculus fistula*, the abdomen contains, in addition to the alimentary canal, two slender tubes, the ovaria and oviducts (*o*, *o*), commencing by blind extremities near the anterior part of the dilated intestine, and continuing with a slightly wavy course to terminate at the two apertures, to which the ovisacs are attached. These ovisacs (*f*) singularly resemble the seed-capsules of certain plants, the *Cassia fistula*, e. g., being divided into a series of cells or chambers by transverse septa, placed at regular distances. Each cell contains an elliptical or lenticular ovum.

Two slender white filaments (*g g*) running almost parallel with, but at a distance from, each other, through the whole length of the under surface of the abdomen, nearer the margins than the middle line, form the chief and most conspicuous part of the nervous system.

The Epizoa differ from one another in their mode of adhering to the fish they infest: some stick fast by a suctorial mouth; others by processes that grow from the head; but the most common mechanism of adhesion in this singular class is a circular sucker, *fig.* 116, *m*, the larva; *g* is the caudal end of the body; *f* the ventral surface, with the aperture of the shell from which the cirrigerous feet protrude: *e* is the dorsal surface. The relative position of the retracted soft parts to the multivalve shell is shown in *fig.* 121.

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* CCIX.

All the sessile Cirripeds are strongly defended by a multivalve conical shell, closed by a four-valved operculum (*fig.* 113). The base of the shell is usually formed by a calcareous plate, and the walls are apparently divided into twelve conical compartments, six of which (*a a*), called "areæ prominentes" and "parietes," rise from the margin of the base, and terminate in a point at the free margin of the shell; whilst the other six (*b b*), in the form of inverted cones, called "areæ depressæ" and "radii," occupy the interspaces of the preceding series. This calcareous citadel is divided into from four to eight pieces by fine sutures. The piece at the part of the shell nearest which the cirri (*c*) are protruded is called the "carina;" the opposite piece is the "rostrum." The symmetry or bilaterality of the shell is determined by these pieces, which have two lateral appendages, called "alæ." Three pieces are, in *Octomeris*, interposed, on each side, between the carina and rostrum. They are called "carino-lateral," "lateral," and "rostro-lateral." The two first have a radius on the carinal side, and an ala on the rostral side; the third piece has a radius on each side. Our common Acorn-shells (*Balanus*, *fig.* 113) have two pieces on each side, the "carino-lateral" and "rostro-lateral." Each piece consists of an outer and inner plate, united by longitudinal plates. The whole shell has a cellular and organised texture, and its gradual expansion is provided for by the successive growth and calcification of processes of the mantle which penetrate the uniting sutures. The cone is lengthened and widened below by successive additions to its base, and is widened superiorly by the gradual increase in breadth of the wedge-shaped pieces of the second or inverted series. In the *Tubicinella* *, a parasitic balanid of the whale, the compound shell is a long subcylindrical tube, reminding us of that of an amphitrite; but the animal, in both sessile and pedunculate Cirripeds, is fixed to the bottom of the shell with the head downwards, and the head is, therefore, superior in the ordinary pendent position of the barnacles (*Lepas*, *fig.* 121).

The external integument consists of chitine †, which also forms the animal basis of the shell ‡; the calcareous part of the latter consists of 99·3 of carbonate of lime, with 0·7 of phosphate of lime §. The chitine is lined by a soft vascular corium, the formative organ of both

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[*] Prep. No. 279.

[†] IX.

[‡] In *Lepas* and *Pollicipes*, CCXXIII. p. 30.

[§] IX

oblique position, like the barbs of a feather, or the vane of an arrow, whence the specific name *Sagitta*, given to this parasite. The caudal lamellæ of the higher Crustacea would seem to be here sketched out.

The anatomy of the Epizoa has been most elaborately traced out by Nordmann* in the parasite of the common perch, called *Achtheres*. In this species two lateral teeth project from the circular mouth, the labial margin of which is fringed with bristles. Here, also, we have mandibles (*b*), and maxillæ, the latter provided with palpi; and, besides these, a pair of jointed antennæ (*c*), each terminated by three setæ. Now, this is a very important external character; it is the first instance of true jointed antennæ that we have met with in our ascending survey of the animal kingdom, and the acute zoologist might be led to surmise, from their presence, that relations of higher affinity were masked beneath the general character of the vermiform body of the parasite, and we shall be able to raise the mask as we trace the metamorphoses of the species. The alimentary canal is, as usual, straight, and terminated by a bituberculate vent (*v*), at the opposite extremity to the head. The abdominal intestine (*d*), is fusiform, and divided by a series of slight constrictions into sacculi. It is maintained in its position by a transverse muscle (*h*). The hepatic organ (*e*) is more concentrated than in the *Peniculus*, and surrounds the anterior part of the canal. The walls of the abdomen are distinctly provided with longitudinal (*i*) and transverse (*k*), fasciculi of muscular fibres. The nervous system consists of a single cephalic ganglion, from which are continued two principal chords (*g*), extending along the under surface of the body.

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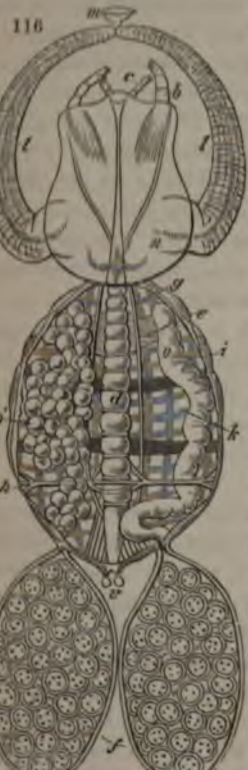

Achtheres, female, magnified.

The circulating fluid consists of a clear plasma, with granular corpuscles of different forms and sizes. The pulsatile vasiform heart may be seen at the middle line of the cephalo-thorax propelling the blood forwards by rythmical contractions. Two canals (*n*), pass from it into the hollow prehensile feet. The rest of the blood is distributed to the head, and along each side of the commencement of the alimentary canal to the under part of the body, where it passes backwards in the vessel which accompanies the intestine.

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* LXXI. Heft. ii.

The ovaria at first appear in the form of a slightly flexuous, long, blind tube, sacculated along one side (*o*, *fig.* 116). As the ova are developed, the ovarium takes on the form of a bunch of grapes, and occupies the whole cavity of the abdomen external to the intestine *o′* : each ovarium terminates by a triangular, and somewhat prominent orifice, to which the external ovisac (*f*) is appended.

The Epizoa are remarkable for the disproportionate size of the sexes. In the minute male (*fig.* 117), the testes are indicated by four dark coloured and finely granulated bodies (*d d*) situated in the posterior segment or abdomen. He appears like a mere parasite of the female to which he adheres, near the vulva, and having usually one antenna inserted into that aperture.

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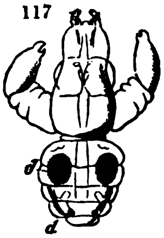

Achtheres, male. Magnified.

The first remarkable circumstance in the natural history of the aquatic Epizoa is the constancy with which particular species infest particular fishes or crustacea. And how, it may be asked, can creatures so devoid of means of transport, nay, in most instances, of the power of detaching themselves from the animals whence, like fœtuses, they derive their means of growth, originally reach the precise species of animal and organ to which they are habitually attached?

Are certain of the ova accidentally retained near the parent after the rupture of the ovisac; and do they there grow, like seeds of plants fallen in a favourable soil? Or, do some of the liberated ova, by a happy fortuity, arrive at the appropriate organ of the appropriate species; and are they there accidentally retained until the prehensile instruments are developed? Such hypotheses may be permitted in reference to the ova of an Entozoon, which are developed by millions, and need only gain an entry into the animal they may infest, or which may be the common food of the species in whose intestine they are adapted to exist; but the ova are too few in the Epizoa, and the parts to which they are attached are too exposed, to allow of the supposition that their parasitic growth is dependent on such accidental circumstances.

MM. Audouin and Edwards appear to have been the first to suggest that the sedentary Lernæan Epizoa might enjoy at a previous period of existence locomotive powers, and the hypothesis was supported by the discovery, made by Dr. Surriray*, of the embryo of a

* CCXI. p. 401.

Lernæocera, still in the ovum, which, instead of resembling th parent, presented the characters of a locomotive Entomostracou monoculous Crustacean.

The singular metamorphosis thus indicated has been traced out an generalised by the careful observations of Dr. Nordmann. Th following is the course of development of the Lernæan parasite of th Perch.

The female Achtheres is devoid of ovigerous appendages in th months of December, January, and February. In March they ar developed by the eversion of a membrane prepared in the ovaria sac. Each sac hangs by a short tubular peduncle which is in direc communication with the short oviduct. The outer membrane of th ovum or chorion is moderately thick and transparent; the inner mem brane is thinner, and includes both the vitelline mass and albumen The yolk forms the largest proportion of the contents of the ovum and is finely granular. One of the first parts of the embryo discerne by Nordmann was the dark ocellus (*fig.* 118, *e.*). A pai of cylindrical processes shoot out from each side of th fore part of the embryonic or vitelline mass; and pencil of hairs is developed from the extremity of eac process. The body (*d*) slightly elongates, the exterio albuminous fluid (*c*) increases, the inner membrane (*b* expands, and the outer one (*a*) bursts and is shed. Th movements of the imprisoned embryo increase in force until it burst the remaining obstacle, and escapes from the ovigerous sac. It the presents the form represented in figur 119. The digestive sac (*h*) is now discernible, together with a peculiar tortuous tub (*g'*), which is continued from the mouth. The locomotive organs are in two pairs, and consist of tubular processes of th integument, including a fasciculus o bristles; they now present the type of those of the Anellids. An since we were led from the Infusoria to the Polypi, because the ciliated larvæ of these resembled the monads, and from the Polypi t the Acalephæ, because these in their larval state were polypes, so w have now the same indication, from a transitory step in development, of the right track in passing from the Annulata to the Epizoa; an the succeeding steps will lead us to place these parasites on a higher grade of articulate structure; and not with the Entozoa, where Cuvier and Lamarck left them.

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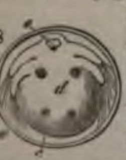
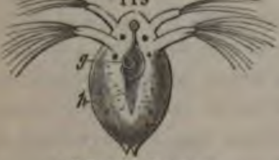


Achtheres. Egg and Embryo.

119



Achtheres: first stage.

In the course of half an hour the young Achtheres undergoes its second stage: the first integument (*e*) is loosened by the formation of a second beneath it, which now incloses a body, altered in its shape and in the number and nature of its appendages (*fig.* 120.).

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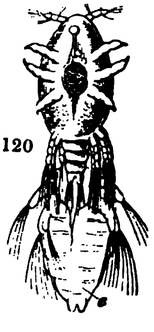

Achtheres: second stage.

The process of moulting lasts from eight to ten minutes. A great proportion of the original germ-mass remains unaltered, surrounding the simple intestine, and extending into the bases of the tubular feet of the larva. The ***nisus formativus*** proceeds to operate on this material, but on a modified plan. The second body, which is formed inside the husk of the first now cast off, is divided into an anterior and a posterior segment, the latter consisting of four joints. A pair of four-articulate setigerous antennæ diverge from the anterior part of the body. Between the antennæ is the large single median eye, as in the monocular Entomostracous Crustacea. The little Epizoon is now provided with five pairs of feet; the first three pairs terminate by a simple hook; the last two pairs are bifurcated, one division being hooked and prehensile, the other tubular and emitting tufts of bristles; these natatory feet strike the water together, and propel the body forward with a jerk; they are aided by the last segment, which is terminated by four setigerous tubercles.

The antennæ probably serve to indicate to the young parasite its appropriate object, to which it then proceeds to attach itself. The first pair of feet is approximated towards the mouth, and forms the uncinated mandibles. The second pair of feet increases in size, and the terminal hook enlarges; they serve to seize and hold on to the surface of the fish selected. The feet of the third pair lengthen and unite together to form a cartilaginous circular sucker, and permanently anchor the parasite to its prey.

The two sexes are alike in their young and locomotive state: the male at its final metamorphosis retains the first pair of feet as mandibles, very similar in form to those of the female: the second pair is shorter and thicker: the legs of the third pair always remain separate from each other, and consist usually each of two large joints, the last one terminated by a claw. The posterior natatory feet disappear in both sexes; and, with the loss of these instruments of locomotion, the eyes, also, are blinded and absorbed.

Before proceeding to the *Cirripedia*, I would offer a few remarks on the nature of the changes just described. They are commonly spoken of under the same name as that given to the changes of insects, and perhaps they differ only in degree. The metamorphosis in all insects is attended with the casting off of a certain proportion of the precedent individual, called the "moult," or the new animal may be said to creep out of the old, from which the process is called the "ecdysis." With regard to the so-called metamorphosis which issues in the succession of a fixed, blind, sessile, multivalve barnacle to a free-swimming crustacean with pedunculated eyes, or in the succession of a rooted vermiform parasite to a natatory animal with articulated setigerous limbs,—when these phenomena are closely traced, they are seen to depend in a greater degree upon the action and coalescence of retained cells, than upon a change of form of pre-existing tissues. If the development of the ovum in the pedunculate ovarian sac of the low crustaceous external parasite of a fish be closely traced, the peripheral cells of the germ-mass are seen to combine and coalesce to form the smooth transparent skin of the embryo Lernæa, from which also tubular processes extend in two (*Achtheres*) or three (*Lernæocera*) pairs, including setæ which project from their extremities.

In the *Lernæocera* the anterior pair is directed forward like antennæ, but they are unjointed; and the head is further indicated by a coloured eye-speck. Another layer of germ-cells have perished, as such, in order to form the parietes of a straight and simple intestine, with a mouth and anus. Thus the anellidous type is first manifested.

But a large proportion of the minute germ-cells remain in the wide abdominal interspace, amassed around the alimentary tube, and aggregated in groups at the base of the tubular and setigerous feet. With respect to the latter, we might say that the same provision is made for the reproduction of the limbs as is retained throughout life in regard to those of the lobster. In the larval Lernæa, however, those reserve-cells commence the formation of new limbs irrespective of any injury to the old ones. The whole peripheral stratum of the retained germ-mass, in contact with the primary integument, is transformed into a new integument. These germ-cells have increased and propagated at the expense of the aliment assimilated by the alimentary canal. The formation of the new integument and of the new feet proceeds connectedly and contemporaneously; but the new parts are not moulded upon the inner surface of the old ones. The plastic force has changed its course of operation. A hinder segment of the body is added to the front one, which answers to the whole of the body of the first larva. If antennæ did not before exist, a joined pair is now developed. Instead of two pairs of tubular setigerous limbs, three pairs of uncinated prehensile limbs are developed from the anterior or cephalothoracic segment, and as many pairs of articulated setigerous limbs from the abdominal segment. New muscles, new nerves, and new vessels are formed for the support and exercise of these various instruments. The outer case, and all that gave form and character to the precedent individual, perish and are cast off; they are not changed into the corresponding parts of the new individual. These are due to a new and distinct developmental process; rendered possible through the retention of a certain proportion of the unchanged germ-cells. The process is essentially the same as that which developes the cercariform larva of the Distoma within the gregariniform one, or the external bud from the Hydra, or the internal bud from the Aphis. It is a slightly modified parthenogenesis; and the phases by which the locomotive anellidous larva of the Lernæa passes through the entomostracous stage before retrograding to the final condition of the oviparous, limbless, bloated, and rooted parasite, are much more those of a metagenesis than a metamorphosis.

I now proceed to the second class of Articulated animals which are associated in the present Lecture with the Epizoa.

Many of the *Cirripedia** are parasitic animals, like the *Epizoa*, but are dependent upon the organised bodies to which they are attached for their place of residence, not for their food; those Cirripeds which do not infest other animals are attached to sea-weed, floating timber, or rocks. The Cirripeds are symmetrical animals, with a soft, obscurely articulated body enveloped in a membrane (*fig.* 121, *c c*); they are provided with six pairs of thoracic feet (ib. *h*), divided into three joints, and terminated each by a pair of long and slender, many-jointed, ciliated tentacles, curled towards the mouth, whence the name of the class. They are androgynous, and in some species there are also small males parasitic on the bisexual individuals.† The mouth (ib. *a*) is prominent, and, in most species, provided with a broad upper lip, with two palps or feelers (ib. *b*), and three pairs of dentated and ciliated jaws. The opposite extremity of the body is prolonged into a slender, many-jointed, ciliated caudal appendage (*fig.* 123, *g*), which is traversed by the generative canal. The mouth is situated near the anterior extremity of the body, which is modified to form the organ of attachment of the animal. It is sometimes produced to a considerable extent, and is of contracted diameter, forming a long and flexible peduncle; sometimes

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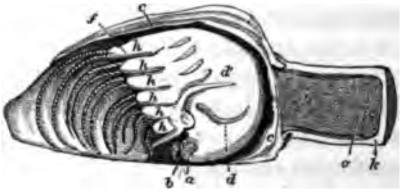

Lepas anatifera.

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* Lat. *cirrus*, a curl, *pes*, a foot.

† CCXXIII. pp. 189. 248.

it expands at once into a broad disc or basis of adhesion; in both cases the immediate attaching substance is a peculiar cement proceeding from a modified portion of the ovaria.* The typical Cirripeds are divided according to these modes of attachment into two primary groups, viz., the pedunculated, or *Lepadoids*, and the sessile, or *Balanoids*. The first are commonly known by the name of Barnacles; the second by that of Crown-shells or Acorn-shells. Such are the characters of the typical members of the class. The aberrant burrowing genus *Alcippe*, and the naked, ventless *Proteolepas*, parasitic on other Cirripeds, form, according to Darwin, types of two orders, equivalent respectively to that including all the ordinary Cirripeds.

Most of these Cirripeds have their visceral cavity protected by a calcareous shell composed of many pieces; but in some, as, e.g. *Alepas*, *Ibla*, the membranous investment of the viscera is enveloped by a smooth elastic sheath, continued from the outer chitinous covering of the peduncle. In *Otion* two small calcareous bodies (*scuta*), developed in the substance of the outer envelope, just above the brachial fissure, are usually the sole rudiments of a shell, and the chitinous covering is produced at its free extremity into two cylindrical plicated ear-like appendages. In the earless Otions (*Cineras*), the external tunic is strengthened by five calcareous bars, two at the fissure (*scuta*), giving outlet to the arms, two along the terminal margin of the tunic (*terga*), and one along the dorsal aspect (*carina*). In the common Barnacle (*Lepas anatifera*), the calcareous matter extends from five homologous centres, so as to protect the whole of the visceral or thoracic-abdominal cavity or body. In *fig.* 122, *c* is the "scutum," *d* the "tergum" and *e* the "carina;" the first two are in pairs, the last is single, and was compared by Cuvier to the symmetrical dorsal valve of the *Pholas*; but the relation is one of analogy only.

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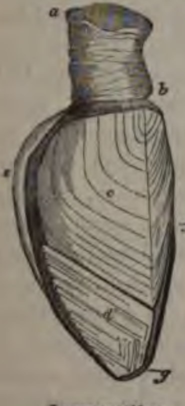

Lepas anatifera.

All the valves, however, are strongly marked with lines of growth, formed by successive additions to their margins, as in the shells of Mollusca. In the genera *Pollicipes* and *Scalpellum*, there are other smaller calcareous plates arranged round the junction of the body with the peduncle. In *fig.* 122, *a* and *b* are the peduncle, which is a development of the head including the aborted eyes and antennæ of the larva; *g* is the caudal end of the body; *f* the ventral surface, with the aperture of the shell from which the cirrigerous feet protrude: *e* is the dorsal surface. The relative position of the retracted soft parts to the multivalve shell is shown in *fig.* 121.

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* CCXXIII. p. 33.

All the sessile Cirripeds are strongly defended by a multivalve conical shell, closed by a four-valved operculum (*fig.* 113). The base of the shell is usually formed by a calcareous plate, and the walls are apparently divided into twelve conical compartments, six of which (*a a*), called "areæ prominentes" and "parietes," rise from the margin of the base, and terminate in a point at the free margin of the shell; whilst the other six (*b b*), in the form of inverted cones, called "areæ depressæ" and "radii," occupy the interspaces of the preceding series. This calcareous citadel is divided into from four to eight pieces by fine sutures. The piece at the part of the shell nearest which the cirri (*c*) are protruded is called the "carina;" the opposite piece is the "rostrum." The symmetry or bilaterality of the shell is determined by these pieces, which have two lateral appendages, called "alæ." Three pieces are, in *Octomeris*, interposed, on each side, between the carina and rostrum. They are called "carino-lateral," "lateral," and "rostro-lateral." The two first have a radius on the carinal side, and an ala on the rostral side; the third piece has a radius on each side. Our common Acorn-shells (*Balanus*, *fig.* 113) have two pièces on each side, the "carino-lateral" and "rostro-lateral." Each piece consists of an outer and inner plate, united by longitudinal plates. The whole shell has a cellular and organised texture, and its gradual expansion is provided for by the successive growth and calcification of processes of the mantle which penetrate the uniting sutures. The cone is lengthened and widened below by successive additions to its base, and is widened superiorly by the gradual increase in breadth of the wedge-shaped pieces of the second or inverted series. In the *Tubicinella* *, a parasitic balanid of the whale, the compound shell is a long subcylindrical tube, reminding us of that of an amphitrite; but the animal, in both sessile and pedunculate Cirripeds, is fixed to the bottom of the shell with the head downwards, and the head is, therefore, superior in the ordinary pendent position of the barnacles (*Lepas*, *fig.* 121).

The external integument consists of chitine †, which also forms the animal basis of the shell ‡; the calcareous part of the latter consists of 99·3 of carbonate of lime, with 0·7 of phosphate of lime §. The chitine is lined by a soft vascular corium, the formative organ of both the calcified and uncalcified chitine. In the growth of the body the membrane between the valves splits periodically, and a new strip of membrane is formed beneath, connected on each side with a fresh layer of shell, the old strips disintegrating and disappearing*, but the valves are not shed. The integument of the peduncle consists, in *Lepas*, of corium, covered by smooth layers of chitine (*fig.* 121, *k*); but in *Scalpellum* and *Pollicipes* its outer surface is roughened by small calcified scales. If the peduncle be very carefully removed from the surface of attachment, the larval antennæ can always be found quite close to the end, but not at the actual apex.†

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* Prep. No. 279.

† IX.

‡ In *Lepas* and *Pollicipes*, CCXXIII. p. 30.

§ IX

The movements of the peduncle in such species are effected by a strong muscular tunic, consisting of three layers of non-striated fibres, longitudinal, transverse, and oblique (ib. *b*). In *Otion* they extend half-way down the sheath of the body‡; and in *Alepas* they line the whole of the body-sheath. The action of these muscles is antagonised by the elasticity of the chitinous tunic. The common Barnacle approximates its scuta by a strong transverse adductor muscle; its body or visceral mass is moved towards the aperture of the shell, which is thereby at the same time widened, by longitudinal muscular fibres, and is retracted by shorter fibres attached to its base. In *Lithotrya* there are two fan-like transverse muscles extending from the basal points of the terga to a central line on the under side of the carina.§ The cirrigerous arms in all the Cirripeds have powerful muscles for their actions, which are of the utmost importance to the animal, inasmuch as the food is obtained by the currents which they produce, and almost incessantly maintain, in the surrounding water. The sessile Barnacles are provided with a series of muscles attached to the margin of the conical shell, which act on the opercular calcareous pieces, and close the opening of the shell.

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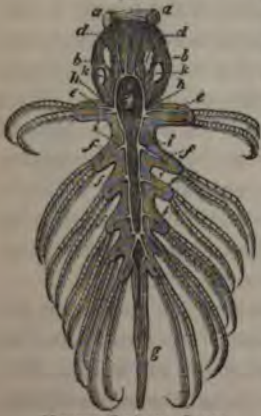

Nervous System. *Lepas*.

The nervous system (*fig.* 123), first described and figured by Cuvier in the *Lepas anatifera*, presents the homogangliate type. The œsophagus is surrounded by a wide oral ring, closed above by a pair of superœsophageal ganglions, which send off nerves to the peduncle, the ovaria, and to the aborted and confluent eyes. Mr. Darwin has detected a small ganglion on each optic nerve in the *Lepas fascicularis*.‖

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* CCXXIII. p. 30.

† Ib. p. 33.

‡ Prep. Nos. 62, 68, 69.

§ CCXXIII. p. 33.

‖ Ib. p. 49.

The ring is completed below by the large subœsophageal ganglion, which gives off the nerves to the trophi, the first pair of cirrigerous feet, and the adjacent muscles. The second thoracic ganglion supplies the second pair of feet; the third ganglion supplies the third pair of feet; the fourth and fifth pairs of ganglions are approximated to each other; and the tubular extensile tail or penis receives the two last pairs of nerves. Two branches from the œsophageal ring pass to a small ganglion on either side of the stomach, from which the alimentary canal is supplied. The nervous system is that part of the organisation of the mature animal which most unequivocally indicates the province of the Animal Kingdom to which the class *Cirripedia* belongs; and it indicates their superiority to the Anellids, and their closer affinity to the crustaceous type by the large size of the confluent ganglions on the abdominal chords. In the degree of approximation of the two chords to each other, the *Lepades* most resemble the lower isopodous Crustacea, for example, the Talitrus. The neurilemma is stained by a dark brown pigment in the *Lepas fascicularis*. In *Pollicipes Mitella*, the fourth and fifth thoracic ganglia are confluent. In the *Balanus tintinnabulum* and *Coronula diadema* all the nerves, save those connected with the brain, radiate from a single great subœsophageal ganglion.*

The acoustic organs are situated just beneath the basal articulation of the first pair of cirri. Each consists of a sac-like cavity, which incloses the true acoustic vesicle. The orifice of the vesicle is closed by a delicate lid, formed by the expansion of a large nerve, which here abruptly terminates.† Mr. Darwin, to whom we owe the knowledge of this structure, has not found any otolites in the acoustic vesicle, but only groups of yellowish nucleated cells in the pulpy fluid. The same excellent observer is of opinion that the pouches situated in the confluent segments beneath the free part of the outer maxillæ are "olfactory;" their orifices are produced or tubular in many Barnacles, but not in the sessile Cirripeds.

Although the eyes of the Cirripeds are more or less aborted in their mature state, they retain sufficient susceptibility of light to excite, in the pedunculated species, when a shadow passes over them, retraction of the cirri, and, in the sessile species, a sudden shutting of their opercules; the same act is caused by the sound or vibration of an approaching footstep; it indicates that they appreciate the atmospheric movements produced by the approximation of the hand, even, according to Dr. Coldstream, when it is not brought nearer the shells than twelve or fourteen inches.‡

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* CCXXIV. p. 88.

† Ib. p. 95.

‡ CCXVI. p. 688.

The marine animalcules brought to the mouth (*fig.* 124, *a*), by the currents of the cirrigerous feet (*b*), and seized by the lateral jaws, are conveyed by a short œsophagus, having a bell-shaped expansion of the lining membrane, to a dilated stomach (*c*), which is of unusual length in *Tubicinella*. From six to eight cæca are developed from the upper part of the stomach, in several species of *Balanus*, and are branched in *Bal. perforatus*. They are not developed in *Tubicinella*. The intestine (*d*) is bent upon the stomach, and tapers with a slightly sinuous course to terminate at (*d'*), the base of the caudal appendage (*e*). The intestinal canal is lined by a chitinous epithelial tube, which is continued above into the cæca. Darwin has observed it to be expelled entire, with the excrement, in a living *Balanus*; it has been deemed analogous to the typhlosole in the earth-worm's intestine.*

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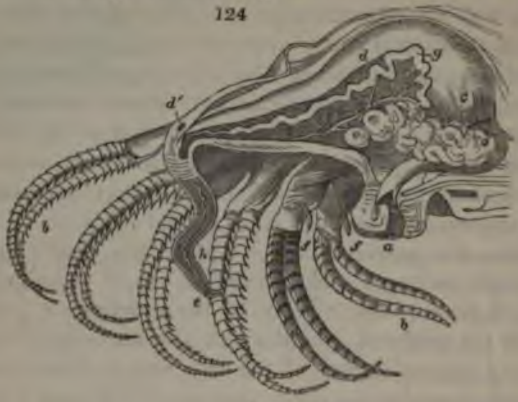

Lepas.

The stomach is coated by small, opaque, pulpy, branched glands, probably subserving a hepatic function: these are arranged in longitudinal lines in most Barnacles.

Poli states that he saw a heart pulsating a little above the anus, and Dr. Coldstream, who quotes the remark, says that there is a "central canal situated on the dorsal aspect of the body;"† but the exact condition of the circulating system of the Cirripeds has yet to be determined, and by the examination of living specimens. Much of it — probably all the venous part — appears to be in the condition of diffused channels or sinuses, defined only by the extremely delicate tunica propria of the veins. There is one main channel along the ventral surface of the thorax, dividing and surrounding the mouth, and giving out branches which enter the inner of the two channels in each thoracic leg; there are also two canals in the penis. "There are two dorso-lateral channels in the prosoma, which are in direct connection with the great main channel, running down the ventral side of the peduncle. This latter main channel branches out in the lower part, and transmits the blood through the ovarian tubes, whence, I believe, it flows upwards and round the sac, re-entering the body near the sides of the adductor scutorum muscle. The main ventral channel, in the uppermost part of the peduncle, has a depending curtain, which, I think, must act as a valve, so as to prevent the circulating fluid regurgitating into the animal's body during the contractions of the peduncle."*

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* CCXV. p. 26.

† CCXVI. p. 689.

In the pedunculated Cirripeds slender appendages, which from their position and connections are homologous with the branchiæ of the higher Crustacea, are attached to, or near to, the bases of a greater or less number of the thoracic feet, and extend in an opposite direction, outside the visceral sac. In the common Barnacle (*Lepas anatifera*) there are two pairs of such branchiæ; the first (*d*, *fig.* 121), is attached to the side of the prosoma, anterior to the first cirrigerous foot, and seems to answer to the gill developed from the last maxillary foot in the lobster; the second appendage (*d'*) springs from the dorsal surface of the swelling (*g*) at the basal joint of the first thoracic foot. In the *Lepas fascicularis* I find one gill attached to the prosoma, and three others radiating from the base of the first thoracic leg.† In the *Otion* there are two gills from the side of the prosoma, and five from the bases of the first five thoracic legs; seven pairs in all, most of which are unusually long and tapering. With respect to the function of these appendages, I concur with Mr. Darwin in deeming them of very secondary importance in respiration, having, like him, always found them occupied by lobes of the testis. The extensive vascular surfaces of the corium and of the body-sac, exposed to the sea-water, with the active cirri themselves, most probably suffice for the aeration of the blood; and the additional expansion of surface, afforded by the plicated tubular appendages to the body of the *Otion*, concurs to effect the same end. The homologues of the branchial appendages of the Barnacles are not present in the Balanids; the respiratory function is here especially aided by the production of plicated folds of the body-sac, which are very numerous and complex in the *Coronula diadema*.‡

The *Cirripedia* are hermaphrodite: there are no known exceptions to this rule in the sessile order: in the pedunculated one a few exceptions have been discovered by Darwin, e. g. *Ibla Cummingii* and *Scalpellum ornatum*, in which the large attached individuals develope ova only, the spermatozoa being formed in distinct and much smaller parasitic males. The same excellent observer has detected similar parasitic individuals, mouthless and stomachless; containing abundant spermatozoa, attached to the larger individuals, possessing both male and female organs, of *Ibla quadrivalvis, Scalpellum vulgare, Sc. rutilum, Sc. rostratum, Sc. Peronii,* and *Sc. villosum,* such supplemental males having specific characters as distinct as those of the hermaphrodite individuals to which they are attached, and in which the vesiculæ seminales are unusually small.

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* CCXXIII. p. 46.

† Prep. No. 994.

‡ Prep. No. 997.

The ordinary hermaphrodite combination of generative organs prevails so far as is hitherto known in all the species of *Lepas, Pæcilasma, Oxynaspis, Anelasma, Pollicipes, Lithotrya, Otion,* and *Cineras.* The male organs consist of two testes, two sperm-bladders with their sperm-ducts, and the penis. The testes consist of minute compressed seminiferous lobes, forming usually a leaden-coloured pyriform digitate or dendritic mass: they coat the stomach, enter the pedicels and basal joints of the cirri, in some genera occupy certain swellings on the thorax and prosoma, and in others penetrate the filamentary appendages. They are confined to the thorax and prosoma in the sessile Cirripeds. The sperm-bladders are, in most species, very large: in the Lepadoids they lie along, and, save in some species of *Scalpellum,* penetrate the prosoma, where their broad ends are often reflexed: here the branched ducts from the testes enter. The coats of the bladder are formed of circular fibres, which Darwin concludes are muscular, having seen the spermatozoa expelled with force from the cut end of a living specimen. The sperm-bladders, as they extend backwards, gradually contract to canals which unite in a single sperm-duct at the base of the penis, or, in *Otion,* half-way along it. In the bell-barnacles (*Balanus*) the sperm-reservoirs are very long and tortuous: they lie within the thorax and prosoma, and unite at the base of the proboscidiform penis. This organ is of great length, except in certain species of *Scalpellum,* and can move freely in all directions; it is supported on a straight unarticulated base, short in most, but in *Ibla quadrivalvis* of great length*: the rest of the extent is more or less distinctly articulated; short hairs project from the intervals of the rings, and more abundantly from the end of the penis.

In the Balanoids the ovaria consist of glandular bodies, of unbranched or main tubes, and of branching tubes and cæca. The ovarian glands are situated near the basal edge of the labrum: the branched tubes lie between the calcareous or membranous basis and the inner basal lining of the sac extending a certain way upwards around the sac. There are no true oviducts. In the Lepadoids the ovaria have a more complex form and extended place: they consist, on each side, of a thoracic and peduncular portion connected by a long unbranched canal. The thoracic ovaria (*fig.* 124, *o*), mistaken by Cuvier for salivary glands, correspond in position with the entire ovaria in the Balanoids: they are of an orange colour, and present the form of two parallel, gut-shaped masses, having, in *Otion*, a great flexure, and generally dividing at the end near the mouth into a few blunt branches. Mr. Darwin, who has given the best account of the female organs in the pedunculated Cirripeds, writes, "The state of these two masses varied much; sometimes they were hollow, with only their walls spotted with a few cellular little masses; at other times they contained, or rather were formed of, more or less globular or finger-shaped aggregations of pulpy matter; and, lastly, the whole consisted of separate pointed little balls, each with a large inner cell, and this again with two or three included granules. These so closely resembled, in general appearance and size, the ovigerms with their germinal vesicles and spots which I have often seen at the first commencement of the formation of the ova in the ovarian tubes in the peduncle, that I cannot doubt that such is their nature."* The connecting canals diverge at the bases of the first pair of limbs, bend along each flank of the prosoma, under the superficial muscles, and converge to penetrate the peduncle, along the ventral side of which they run close together, and, when half-way towards the end, begin to branch out in all directions; the ova being developed within the stems of the branches as well as at their ends. "A minute point first branches out from one of the tubes, its head enlarges like the bud of a tulip on a footstalk; becomes globular, shows traces of dividing, and at last splits into three, four, or five egg-shaped balls, which finally separate as perfect ova"† (*fig.* 121, *i*).

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* CCXXIII. p. 56. pl. iv. fig. 9 *a.*

According to the same author, the ova, immediately before one of the periods of exuviation, burst forth from the ovarian tubes in the peduncle, and round the sack of the animal, and, moving "along the open circulatory channels, are collected (by means unknown to me) beneath the chitine tunic of the sack, in the corium, which is at this period remarkably spongy and full of cavities." The corium forms or "resolves itself into the very delicate membrane separately enveloping each ovum, and uniting them together into two lamellæ: the corium having thus far retreated, then forms, under the lamellæ, the chitine tunic of the sac, which will of course be of larger size than the last-new animal may be said to creep out of the old, from which the process is called the "ecdysis." With regard to the so-called metamorphosis which issues in the succession of a fixed, blind, sessile, multivalve barnacle to a free-swimming crustacean with pedunculated eyes, or in the succession of a rooted vermiform parasite to a natatory animal with articulated setigerous limbs,—when these phenomena are closely traced, they are seen to depend in a greater degree upon the action and coalescence of retained cells, than upon a change of form of pre-existing tissues. If the development of the ovum in the pedunculate ovarian sac of the low crustaceous external parasite of a fish be closely traced, the peripheral cells of the germ-mass are seen to combine and coalesce to form the smooth transparent skin of the embryo Lernæa, from which also tubular processes extend in two (*Achtheres*) or three (*Lernæocera*) pairs, including setæ which project from their extremities.

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* CCXXIII. p. 57.

† CCXXIII. p. 57.

In the *Lernæocera* the anterior pair is directed forward like antennæ, but they are unjointed; and the head is further indicated by a coloured eye-speck. Another layer of germ-cells have perished, as such, in order to form the parietes of a straight and simple intestine, with a mouth and anus. Thus the anellidous type is first manifested.

But a large proportion of the minute germ-cells remain in the wide abdominal interspace, amassed around the alimentary tube, and aggregated in groups at the base of the tubular and setigerous feet. With respect to the latter, we might say that the same provision is made for the reproduction of the limbs as is retained throughout life in regard to those of the lobster. In the larval Lernæa, however, those reserve-cells commence the formation of new limbs irrespective of any injury to the old ones. The whole peripheral stratum of the retained germ-mass, in contact with the primary integument, is transformed into a new integument. These germ-cells have increased and propagated at the expense of the aliment assimilated by the alimentary canal. The formation of the new integument and of the new feet proceeds connectedly and contemporaneously; but the new parts are not moulded upon the inner surface of the old ones. The plastic force has changed its course of operation. A hinder segment of the body is added to the front one, which answers to the whole of the body of the first larva. If antennæ did not before exist, a joined pair is now developed. Instead of two pairs of tubular setigerous limbs, three pairs of uncinated prehensile limbs are developed from the anterior or cephalothoracic segment, and as many pairs of articulated setigerous limbs from the abdominal segment. New muscles, new nerves, and new vessels are formed for the support and exercise of these various instruments. The outer case, and all that gave form and character to the precedent individual, perish and are cast off; they are not changed into the corresponding parts of the new individual. These are due to a new and distinct developmental process; rendered possible through the retention of a certain proportion of the unchanged germ-cells. The process is essentially the same as that which developes the cercariform larva of the Distoma within the gregariniform one, or the external bud from the Hydra, or the internal bud from the Aphis. It is a slightly modified parthenogenesis; and the phases by which the locomotive anellidous larva of the Lernæa passes through the entomostracous stage before retrograding to the final condition of the oviparous, limbless, bloated, and rooted parasite, are much more those of a metagenesis than a metamorphosis.

I now proceed to the second class of Articulated animals which are associated in the present Lecture with the Epizoa.

Many of the *Cirripedia** are parasitic animals, like the *Epizoa*, but are dependent upon the organised bodies to which they are attached for their place of residence, not for their food; those Cirripeds which do not infest other animals are attached to sea-weed, floating timber, or rocks. The Cirripeds are symmetrical animals, with a soft, obscurely articulated body enveloped in a membrane (*fig.* 121, *c c*); they are provided with six pairs of thoracic feet (ib. *h*), divided into three joints, and terminated each by a pair of long and slender, many-jointed, ciliated tentacles, curled towards the mouth, whence the name of the class. They are androgynous, and in some species there are also small males parasitic on the bisexual individuals.† The mouth (ib. *a*) is prominent, and, in most species, provided with a broad upper lip, with two palps or feelers (ib. *b*), and three pairs of dentated and ciliated jaws. The opposite extremity of the body is prolonged into a slender, many-jointed, ciliated caudal appendage (*fig.* 123, *g*), which is traversed by the generative canal. The mouth is situated near the anterior extremity of the body, which is modified to form the organ of attachment of the animal. It is sometimes produced to a considerable extent, and is of contracted diameter, forming a long and flexible peduncle; sometimes

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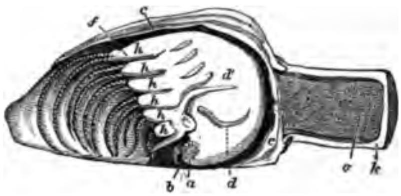

Lepas anatifera.

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* Lat. *cirrus*, a curl, *pes*, a foot.

† CCXXIII. pp. 189. 248.

formed one, now immediately to be moulted with the other integuments of the body. As soon as this exuviation is effected, the tender ova, united into two lamellæ, and adhering as yet to the bottom of the sac, are exposed: as the membranes harden, the lamellæ become detached from the bottom of the sac, but are prevented from being washed out by becoming united to semicircular folds of skin continued from each side of the point of attachment of the body to the sac. These folds, or "fræna," usually large, but in *Ibla* minute, are formed of chitine with underlying corium, and their free border is beset with minute pedunculate or clavate glandular bodies, secreting an adhesive substance serving to unite the ovigerous lamellæ to the fræna. In some species of *Pollicipes* the frænal folds are destitute of the glands, and do not subserve the function allotted to them in other Lepadoids.

Mr. Darwin, to whom we owe the above details, is of opinion that the lamelliform gills of the Balanoids are the homologues of the fræna. "The ova are impregnated (as I infer from the state of the vesiculæ seminales) when first brought into the sac; and whilst the membrane of the lamellæ is very tender the long proboscidiform penis seems well adapted for this end. In the male of *Ibla Cummingii*, which has not a probosciformed penis, the whole flexible body, probably, performs the function of the penis: in *Scalpellum ornatum*, however, the spermatozoa must be brought in by the action of the cirri, or of the currents produced by them. That cross impregnation may, and sometimes does take place, I infer from the singular case of an individual in a group of *Balani*, in which the penis had been cut off, and had healed without any perforation; notwithstanding which fact, larvæ were included in the ova."

Mr. Darwin has shown that the organ, by the secretion of which the Cirripeds attach themselves to foreign bodies, is a modified part of the ovarian tube. In the Lepadoids there are two cement-glands, situated high up in the midst of the ovarian cæca, with one cement-duct proceeding from each; the cement issues from the prehensile antennæ, and in some cases, at a later period, it escapes through apertures in the peduncle. In the Balanoids, at each period of growth a pair of new cement-glands is developed, larger than those last formed, and making, with the older glands, a chain connected together by the cement-trunk. They all adhere to the basal membrane or the basal shelly plate.

The supplemental male of the *Scalpellum vulgare* (*fig.* 125) is found attached over the fold in the occludent margin of the scutum of the large hermaphrodite individual; and is sometimes imbedded more than half its length in the spinigerous chitine. It is an ovate, compressed, flask-like body, having a fimbriated orifice (*a*) at one end: a little behind this are four obtuse bristly processes (*b*); and behind them are four little calcareous nodules, or rudimental valves. The cavity of the body contains a brownish pear-shaped bag, containing, in some individuals, a mass of spermatozoa. With this testis are connected small vesiculæ seminales, and Mr. Darwin believes he has distinguished an orifice at the end of the abdomen. After the most careful dissection of very many specimens, he can positively affirm that there is no vestige of mouth or masticatory organs, stomach, or intestine.*

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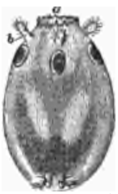

Supplemental male, Scalpellum vulgare.

When we reflect on the uniformity of distribution of the Cirripeds, particular species being attached to particular objects, and these not always stationary and extended bodies, but often living animals, and sometimes animals with quick powers of locomotion; when we further call to mind that they adhere, not by prehensile jaws or feet, but by the growth of a pedunculated root, or by the gradual application of a layer of cement forming the base of their shell; we must be convinced that the organisation and properties of the fettered animal are wholly inadequate to afford an insight into the process by which it acquired its resting-place; and that a knowledge of the previous career from the time of quitting the egg is not less essential to an explanation of the subsequent attachment of the *Cirripedia*, than it was for the elucidation of corresponding phenomena in the *Epizoa.*

No fortuitous dispersion of ova giving origin at once to a pedunculated or sessile multivalve can account for the invariable attachment of the *Coronula* to the skin of the whale, and of the *Otion* to the shell of the parasitic *Coronula;* of the *Chelonobia* to the carapace of the turtle, of the *Cineras* to the tail of the sea-serpent, or of the imbedding of the *Acasta* in the substance of a sponge. These remarkable phenomena have been explicable only since the discovery of the singular metamorphoses which the Cirripeds undergo, and of the power which they possess, at one period of their existence, of attaining and selecting their peculiar and appropriate place of permanent abode. Nor were the real nature and affinities of this singular shell-covered class of animals less problematical and doubtful before the phenomena of their development had been traced out.

Mr. V. Thompson, whose minute and careful researches into the natural history of marine animalcules have thrown much light on the structure and development of radiated animals, was also rewarded by the discovery of the metamorphosis of the Cirripeds.† On the 28th of

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* CCXXIII. pp. 234, 235.

† CCXXV. Memoir iv.

April, 1823, he captured, with a small muslin towing net, a number of translucent animalcules, about the tenth of an inch in length, of a subelliptic form, slightly compressed, and of a brownish tint; the body of each was defended by a shell composed of two valves, joined by a hinge along the back, and opening along the opposite margin for the protrusion of a large and strong anterior pair of limbs (*fig.*126, *a*), provided with an adhesive sucker and hooks, and of six pairs of posterior jointed members (*b*), terminated by a pencil of bristles. These natatory limbs acted in concert, so as to cause the animal to swim by a succession of bounds like the water fleas (*Daphnia*). The body was terminated by a short tail (*e*), composed of two setigerous joints. A pair of pedunculated compound eyes (*d*) was attached to the anterior and lateral part of the body. Other specimens of this little seeming crustaceous animal were taken on the 1st of May, and preserved alive in a glass vessel of sea-water. On the night of the eighth two of them had thrown off their outer skin, and were firmly adhering to the bottom of the vessel, where they rapidly assumed the form of the young of the sessile Barnacle called ***Balanus pusillus.*** The sutures between the valves of the shell and of the operculum were visible, and the arms, though not yet perfectly developed, were seen moving within. The eyes also were still perceptible, although the principal part of the black colouring matter appeared to have been thrown off with the exuvium. On the 10th of May another individual was seen in the act of throwing off its exuvium, and attaching itself to the bottom of the glass. As the calcification of the shell proceeds, the eyes gradually disappear, and the visual ray is extinguished for the remainder of the animal's life. The arms at the same time acquire their usual ciliated structure.

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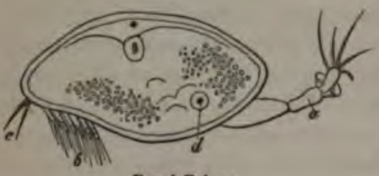

Pupal Balanus.

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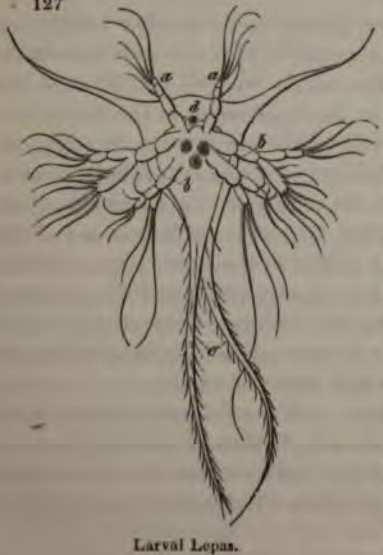

Larval Lepas.

In a subsequent memoir*, Mr. Thompson described and figured larvæ of the *Lepas* and *Cineras.* The young *Lepas*, at the stage at which it was observed, somewhat resembles the entomostracous genus *Cyclops* (*fig.* 127). It has a single median sessile eye-speck, three pairs of members, the most anterior of which are simple, the others bifid. The back of the animal is covered, like the *Argulus armiger*, by an ample shield, terminating anteriorly in two extended horns, and posteriorly in a simple elongated spinous process.

The discoveries of Mr. Thompson have been abundantly confirmed by Audouin †, Wägner ‡, Burmeister §, Goodsir ||, Bates ¶, and Darwin.**

In a few Cirripeds, *e. g.*, the species of *Cryptophialus*, the changes from the egg to the pupa take place within the sack of the parent.

Fig. 127 illustrates the form of the "larva," or first stage, in both pedunculated and sessile Cirripeds, at least after the second moult. Before the moult, the horns, including the second antennæ and the caudal appendages *c*, are less developed; and are always shorter in *Balanus* than in *Lepas.* The general form of the larva is a depressed oval, the body inarticulate, with a carapace covering the dorsal surface. The eye (*d*) often appears to be due to a confluence of two eyes. Behind the eye there arise a minute pair of horns, or sheaths containing the rudimental antennæ of the first pair. The large lateral horns (*e*, *e*) contain the second pair of antennæ; they are amongst the earliest developed organs, as in the larvæ of the Crustacea. The mouth is more or less proboscidiform, and is situated between the first or second pairs of natatory legs; the œsophagus extends from it anteriorly, as in *Limulus.* The first pair of natatory legs has a simple terminal joint; the second and third pairs have bifid terminal joints, or are biramous, in all the genera, as in *Lepas* (*fig.* 127). Darwin regards the natatory limbs as answering to the second, third, and fourth thoracic limbs in the Crustacea. Behind these limbs the trunk is produced, and terminates in a horny forked appendage, which becomes much elongated, as in *fig.* 127, after the first moult. In some larvæ a second, and even a third fork, then appears, indicative of an articulated abdomen.

In the second stage of the larva the carapace is much changed: the second or great antennæ become prehensile organs; the first pair disappears; the eye has become double; but the mouth is still simply suctorial, although advanced in position. The three pairs of thoracic limbs retain their larval character.

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* CCXXVI.

† CCXXVII. p. 31.

‡ CCXXIX. p. 467.

§ CCXIV.

|| CCXXX. pl. iii. and iv.

¶ CCXXVIII. pl. 6, 7, and 8.

** CCXXIII. and CCXXIV. p. 102.

In the third or pupal stage, the anterior natatory legs become, like the others, bifid or biramous: and three posterior pairs of legs are superadded; the small abdomen becomes defined from the thorax. The prehensile antennæ are freed from their cases; the two eyes stand further apart. The carapace consists of two portions, like the valves of a bivalve shell, which fold over and include the thorax and abdomen and their appendages, permitting also the prehensile antennæ (*fig.* 126, *a*) to be beat back within the lower edge. The two valves of the shell are drawn together by an adductor muscle, which crosses anterior to the basal margin of the mouth. Darwin has observed the pupa of the *Lepas australis* to "swim very rapidly, and often on one side, in a circle; it could walk by the aid of its antennæ, but it often fell over." The antennæ are the organs by which the young Cirriped finally anchors itself to the spot where its future adult existence is to be spent. The cement-ducts may be traced as far as the third or disc-segment of the antennæ. There the cement seems to transude, and to fasten down the disc: soon both antennæ are surrounded by a common border of cement, which gradually increases in extent after the metamorphosis. In the *Lepas fascicularis*, the cement is poured out in sufficient quantities to form, itself, the substance to which the peduncle of the adult barnacle adheres, and, for a cluster of which barnacles it constitutes a central vesicular float, as may be seen in the preparations, Nos. 275 and 276, Nat. Hist. Series, Hunterian Museum.

The three terminal segments of the antennæ, into which the cement-ducts are prolonged, are retained in an otherwise functionless condition, in the young Cirriped. The mouth is formed under that of the pupa, with a new œsophagus round the old œsophagus, leading into the same alimentary canal. The twenty-four extreme tips of the six pairs of biramous cirri of the young Cirriped are formed within the twenty-four extremities of the six pairs of biramous natatory legs of the pupa. "Consequently," writes Darwin, "in the Cirripede and pupa, thus far, part corresponds with part, notwithstanding that new eyes are formed posteriorly to the old eyes, and new acoustic organs in a quite different position from the old ones; but now we come to a most important diversity in the metamorphosis, or rather, to follow Professor Owen *, in the metagenesis, of the young Cirripede. Although, as just stated, the extremities of the cirri are formed within the legs of the pupa, yet, from the great length of the cirri, they occupy more than the whole of the thorax of the pupa; so that the thorax of the young Cirripede is not formed within

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* Parthenogenesis, pp. 13 and 26.

the pre-existing thorax of the pupa, but within that part of the pupa (homologically a portion of the first three cephalic segments) which lies anterior to the thorax. As a consequence of this, the pedicels and lower portions of the cirri, the segments of the thorax and its dorsal surface, all come to occupy a position at nearly right angles to that of the corresponding parts in the pupa. And, as a further consequence (and this is a more important point), the sack, which both in the young Cirripede and pupa is formed by the overhanging and produced portion of the carapace, and which is *internally lined by a reduplication of the membrane of the thorax,* is necessarily, owing to the changed position of the thorax, altered in extent and carried much further; namely, from extending merely parallel to the longitudinal axis of the pupa, it is now, in the young Cirripede, in addition, carried almost quite across the inside of the animal. Hence it comes that the young Cirripede is internally almost intersected; and its body remains attached only by a small space to the sternal or ventral inner surface of the carapace,—the carapace being modified either into the capitulum and peduncle, or into the shell with its operculum and basis. As a still further consequence of this change of position of the body of the young Cirripede within the body of the pupa, the alimentary canal becomes shortened to fully half its former length. At the same time, the interspace between the mouth and first pair of legs of the pupa (consisting of the seventh and eighth segments of the archetype) is quite lost in the Cirripede by coalescence. The first cause of the thorax of the young Cirripede not being developed within the thorax of the pupa, probably is, that the cirri may be formed of considerable length, so as to be immediately able to seize prey; and that the thorax, which supports the cirri (and this probably is even more important), should be as free as possible within the sack, so as to aid the captorial action of the cirri."*

When the due time for the act of metamorphosis has arrived, the pupal carapace splits along the dorsal ridge, and is cast off together with the acoustic sacks, the basal segments of the two antennæ, and the great black compound eyes. "Besides the split along the dorsal ridge, the carapace separates all round the orifice from the delicate tunic lining the sack and investing the thorax and natatory legs of the pupa; for those membranes are not moulted for some considerable time afterwards. Hence all these inner parts retain for a period the appearance and structure of the natatory pupa, whilst the exterior resembles in every respect a fixed and perfect cirripede."†

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* CCXXIV. p. 123.

† Ib. p. 126.

Of this most singular form of Articulate animal, the same acute Observer from whom the above passages are quoted has determined analytically the common pattern on which the cirripedial modifications have been superinduced. The archetype consists of seventeen segments, the first fourteen of which, as in the Crustacea, constitute the cephalo-thorax; the other three are abdominal segments. The two pairs of antennæ and the eyes determine the first three segments of the head; the three pairs of jaws mark the next three segments; and the seventh cephalic differs from the succeeding seven thoracic segments. In all the common cirripeds two segments disappear: these Mr. Darwin believes to be the last cephalic and the first thoracic; and the six pairs of cirri belong therefore to the six last thoracic segments.

The general analogy of the pedunculated cirriped to the typical Crustacea, and the true nature of the peduncle, will be best understood by the diagram reduced in *fig.* 128, from Mr. Darwin's monograph.

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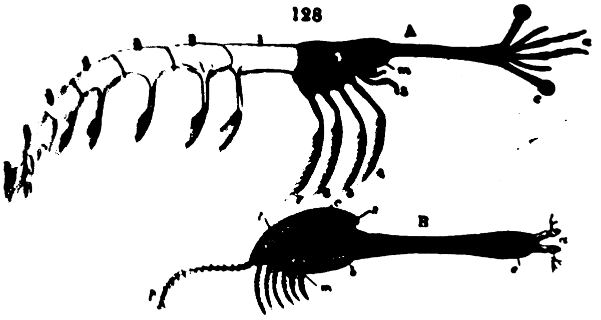

A. Lucifer. B. Lepas.

The upper figure is of a stomapod crustacean: the abdomen, which in cirripeds is rudimentary, is given in outline. The lower figure is a mature Lepas, with the outer antennæ (*a*) and eyes (*e*), which are actually present in the larva, retained and figured of proportionate size. All that we see externally of a cirriped, whether pedunculated or sessile, is the three anterior segments of the head of a crustacean, with its anterior end permanently cemented to a surface of attachment, and with its posterior end projecting vertically from it.

The capitulum, or shell, answers to the carapace in higher crustaceans, which is a backward production of the tergal elements of the third segment. It is divided into (*s*) the scutum, (*t*) the tergum, and the dorsal line of splitting is defended by the narrow carinal piece *c*; *b* is the basis of the capitulum, compound carapace or shell; *m*, the position of the mouth; *p*, the termination of the intromittent organ, developed from the vertical surface of the apex of the abdomen, but not, according to Darwin, the modified homologue of the abdomen.

Class EPIZOA.

Body, chitinous, vermiform, subarticulated, not always symmetrical; with antennæ and articulated limbs terminated either by suckers, hooks, or bristles. Vascular system diffused: white blood. No respiratory organs. Diœcious. Males small or rudimentary: females with external pendent ovisacs. *Metagenesis* resulting in a usually permanent parasitic attachment on the bodies of fishes.

The class is subdivided according to the mode of that attachment.

Order I. Cephaluna.*

Attachment by cephalic processes, sometimes numerous and complex.

Genera *Peniculus*, *Lernœa*, *Chondracanthus*, *Lernæocera*, *Penella.*

Order II. Brachiuna.

Attachment by a suctorial disc at the confluent extremities of the last pair of thoracic limbs.

Genera *Achtheres*, *Tracheliastes*, *Brachiella*, *Lernæopoda*, *Anchorella.*

Order III. Onchuna.

Attachment by hooks at the free extremities of the first pair of thoracic limbs.

Genera *Dichelestium*, *Lamproglena*, *Ergasilus*, *Nicothoë.*

Class CIRRIPEDIA.†

Body, chitinous or chitino-testaceous, subarticulated, mostly symmetrical, with aborted antennæ and eyes. *Mouth*, prominent, composed of a labrum, palpi, two mandibles, and two pairs of maxillæ. *Thorax*, attached to the sternal internal surface of the carapace, with six pairs of multiarticulate, biramous, setigerous limbs. *Abdomen*, rudimentary; vascular system diffused: white blood. Branchiæ, when present, attached to the inferior lateral part of the surface. Most are hermaphrodite; a few have minute rudimentary male individuals parasitically attached to the females. *Penis*, proboscidiform, develope ova only, the spermatozoa being formed in distinct and much smaller parasitic males. The same excellent observer has detected similar parasitic individuals, mouthless and stomachless; containing abundant spermatozoa, attached to the larger individuals, possessing both male and female organs, of *Ibla quadrivalvis*, *Scalpellum vulgare*, *Sc. rutilum*, *Sc. rostratum*, *Sc. Peronii*, and *Sc. villosum*, such supplemental males having specific characters as distinct as those of the hermaphrodite individuals to which they are attached, and in which the vesiculæ seminales are unusually small.

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* κεφαλή, the head, and εὐνή, a bed or last resting-place, in the plural "anchors."

† In the characters and subdivision of this class I have followed Darwin.

The ordinary hermaphrodite combination of generative organs prevails so far as is hitherto known in all the species of *Lepas*, *Pæcilasma*, *Oxynaspis*, *Anelasma*, *Pollicipes*, *Lithotrya*, *Otion*, and *Cineras*. The male organs consist of two testes, two sperm-bladders with their sperm-ducts, and the penis. The testes consist of minute compressed seminiferous lobes, forming usually a leaden-coloured pyriform digitate or dendritic mass: they coat the stomach, enter the pedicels and basal joints of the cirri, in some genera occupy certain swellings on the thorax and prosoma, and in others penetrate the filamentary appendages. They are confined to the thorax and prosoma in the sessile Cirripeds. The sperm-bladders are, in most species, very large: in the Lepadoids they lie along, and, save in some species of *Scalpellum*, penetrate the prosoma, where their broad ends are often reflexed: here the branched ducts from the testes enter. The coats of the bladder are formed of circular fibres, which Darwin concludes are muscular, having seen the spermatozoa expelled with force from the cut end of a living specimen. The sperm-bladders, as they extend backwards, gradually contract to canals which unite in a single sperm-duct at the base of the penis, or, in *Otion*, half-way along it. In the bell-barnacles (*Balanus*) the sperm-reservoirs are very long and tortuous: they lie within the thorax and prosoma, and unite at the base of the proboscidiform penis. This organ is of great length, except in certain species of *Scalpellum*, and can move freely in all directions; it is supported on a straight unarticulated base, short in most, but in *Ibla quadrivalvis* of great length*: the rest of the extent is more or less distinctly articulated; short hairs project from the intervals of the rings, and more abundantly from the end of the penis.

In the Balanoids the ovaria consist of glandular bodies, of unbranched or main tubes, and of branching tubes and cæca. The ovarian glands are situated near the basal edge of the labrum: the branched tubes lie between the calcareous or membranous basis and the inner basal lining of the sac extending a certain way upwards around the sac. There are no true oviducts. In the Lepadoids the ovaria have a more complex form and extended place: they consist, on each side, of a thoracic and peduncular portion connected by a long unbranched canal. The thoracic ovaria (*fig.* 124, *o*), mistaken by Cuvier for salivary glands, correspond in position with the entire ovaria in the Balanoids: they are of an orange colour, and present the form of two parallel, gut-shaped masses, having, in *Otion*, a great flexure, and generally dividing at the end near the mouth into a few blunt branches. Mr. Darwin, who has given the best account of the female organs in the pedunculated Cirripeds, writes, "The state of these two masses varied much; sometimes they were hollow, with only their walls spotted with a few cellular little masses; at other times they contained, or rather were formed of, more or less globular or finger-shaped aggregations of pulpy matter; and, lastly, the whole consisted of separate pointed little balls, each with a large inner cell, and this again with two or three included granules. These so closely resembled, in general appearance and size, the ovigerms with their germinal vesicles and spots which I have often seen at the first commencement of the formation of the ova in the ovarian tubes in the peduncle, that I cannot doubt that such is their nature."* The connecting canals diverge at the bases of the first pair of limbs, bend along each flank of the prosoma, under the superficial muscles, and converge to penetrate the peduncle, along the ventral side of which they run close together, and, when half-way towards the end, begin to branch out in all directions; the ova being developed within the stems of the branches as well as at their ends. "A minute point first branches out from one of the tubes, its head enlarges like the bud of a tulip on a footstalk; becomes globular, shows traces of dividing, and at last splits into three, four, or five egg-shaped balls, which finally separate as perfect ova"† (*fig.* 121, *i*).

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* CCXXIII. p. 56. pl. iv. fig. 9 *a*.

According to the same author, the ova, immediately before one of the periods of exuviation, burst forth from the ovarian tubes in the peduncle, and round the sack of the animal, and, moving "along the open circulatory channels, are collected (by means unknown to me) beneath the chitine tunic of the sack, in the corium, which is at this period remarkably spongy and full of cavities." The corium forms or "resolves itself into the very delicate membrane separately enveloping each ovum, and uniting them together into two lamellæ: the corium having thus far retreated, then forms, under the lamellæ, the chitine tunic of the sac, which will of course be of larger size than the last-

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* CCXXIII. p. 57.

† CCXXIII. p. 57.

LECTURE XIV.

CRUSTACEA.

The class of invertebrated animals which forms our present subject may be regarded, from one point of view, as having been entered upon in the preceding Lecture; for, were we cognisant of the Lernæans and Cirripeds in no other than their locomotive state, we might be led, with those naturalists who judge of an animal from one of its vital stages only, to classify them with the Crustacea, and the pupal barnacles more especially with the bivalve Entomostracans. All Crustacea, however, differ from the Epizoa in being branchiferous; and from the Cirripedia in being diœcious, with well-developed males. And the subjects of the preceding Lecture must have sufficiently impressed us with the necessity of careful investigation of problematic species at every stage of their development, in order to determine their affinities and position in the scale of nature.

In tracing the progressive march of structural complications in the animal kingdom, we see that the organs of vegetative life much more rapidly acquire their full development than those of animal life; and, in reference to the latter, we find a more regular gradation of perfection as the classes ascend in the scale. Take the Articulate sub-kingdom for example. The *Entozoa* may show a complete alimentary canal, with mouth and vent, and with salivary and biliary cœca: they may have the sexes separate, and the male and female organs marvellously developed; yet be devoid of every trace of a locomotive organ, and have a smooth, soft, continuous, lubricous integument. In the *Annulata* we found the integument firmer, but alternately harder and softer, so as to be divided into segments with flexible articulations; and in the higher forms of this class, each of the joints was provided with distinct limbs, although these presented the lowest form of such, e. g., as simple tubes including protractile setæ. In the larval *Epizoa* we saw the limbs presenting a true jointed structure, but lost or becoming more or less abortive in the fixed adults; whilst in the *Cirripedia* several pairs of jointed limbs are retained in the adult state, but their rapid actions are subservient to the acquisition of food, not to locomotion.

We make the easiest and most natural transition from the lower forms of Articulata to the Crustaceous class, by passing to it from the larval state,—which I have argued to be the typical one*,—of the *Epizoa* and *Cirripedia;* in which view we may regard the *Crustacea* as representing those larvæ on a gigantic scale, and so retaining the typical character with the faculty of locomotion.

We thus arrive at a class of articulated animals in which some or all of the annular segments of the skeleton of the body are constantly provided with articulated limbs or appendages, in which all the species are free and locomotive, and are provided with distinct respiratory organs. These animals are still, however, aquatic; only a part of the class can support themselves and move with their jointed limbs on dry land; the highest act of locomotion is that of climbing reeds or trees, which a few species of the present class are enabled to effect by long prehensile claws. But the breathing organs in all the species are organised for aquatic respiration; in other words, are branchiæ; and it is the combination of branchiæ with jointed limbs and distinct sexes which constitutes the essential character of the class *Crustacea.*

The name of this class refers to the modification of the external tegument by which it acquires due hardness for protecting the rock-dwelling marine species from the concussion of the surrounding elements and from the attacks of enemies, and for forming the levers and points of resistance in the act of supporting the body and moving along the firm ground. The animal basis of this external skeleton is the same peculiar tissue as in the two foregoing classes, viz., chitine, which is insoluble in caustic potash, and is charred, not consumed, by fire. In the crab and lobster tribes the integument is hardened by the addition of earthy particles, consisting of the carbonate with a small and varying proportion of the phosphate of lime. This crust is coloured by a pigmental substance, diffused more or less irregularly through its outer surface: its basis being a vascular organised membrane, or corium. The crust exhibits a minutely tubular structure†, is covered by a thin chitinous layer composed of hexagonal cells‡, and it is lined by a thin fibrous membrane, which plays an important part in the moulting process. The tubercles and bristles which beset many parts of the shell are prolongations of it, or its basis—chitine. In the smaller Crustacea the tegument retains a flexible pergameneous character, and is usually so transparent as to allow the internal coloured parts to appear through it.

Whatever be the consistence of the external integument or skeleton, it is always disposed in a series of segments, either actually separate and moveable on each other, or confluent in a variable extent and

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* A character indicative of type is not to be confounded with the sum of characters determinative of class.

† XXIV. p. 420.

‡ CCXXXI. vol. ii. p. 393.

degree, so as more or less to obliterate the traces of their primitive distinctness. The segments are variously proportioned and combined, so as commonly to permit the entire body to be divided into three parts, viz., the head, the thorax, and the abdomen; and most of the Crustacea manifest their peculiarly distinctive forms by different combinations and proportions of the same number of primary rings or segments. Each ring, again, consists of certain elementary parts, which, by varying their proportions, contribute to the peculiar form of the region of the body into the formation of which they enter.

There may be distinguished in the annular segment of a Crustacean, a dorsal arch and a sternal arch, each consisting of a median and two lateral elements: the lateral elements in the upper arch are called "epimeral," and in the lower one "episternal," pieces; the middle element above, or "tergum," consists of two pieces united in the middle line, and that below, or the "sternum" has the same structure. In a great proportion of the class the body consists of twenty-one of these rings, of which seven are more or less blended together to form the head (*fig.* 129, *c*), seven more obviously enter into the formation of the thorax (*g*, *g*), and the remaining seven constitute the abdomen or tail (*a b*).*

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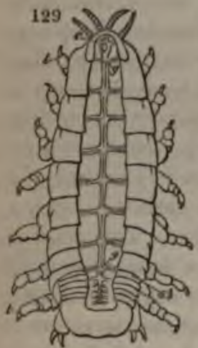

Cymothoa.

The Crustacea, with seven thoracic and seven abdominal segments, form the sub-class *Malacostraca*†; but a few large species and a very great proportion of the smallest members of the class have the thorax and the abdomen composed respectively of a greater or a less number of constituent segments than seven: these Crustacea form the sub-class *Entomostraca*. The best-marked group, that including the largest species of this sub-class, is named *Xiphosura*, because the last segment of the body forms a long three-edged sharp-pointed weapon: it is typified by the *Limulus*, or Molucca crab, in which the head and thorax are more completely blended together than in the true crabs, which they resemble in the general form of the body; but they are peculiarly distinguished from all other Crustacea by having the office

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* CCXXXII.

† In the larger species of Crustacea, where the chitine is combined with such a proportion of carbonate and phosphate of lime as to be firm and brittle, it is, as Aristotle has observed, less hard and less brittle than the shell of the mollusks, whence that philosopher called those Testacea *Ostracoderma*, but gave to the Crustacea the name of *Malacostraca*, which name is still retained for that division of the class which alone was known to the Greek naturalist.

of jaws performed by the basilar joint of the six pairs of thoracic legs, which surround the mouth, the internal branch of those legs forming an ambulatory and prehensile member. The large cephalo-thoracic segment is protected above and laterally by an expanded crescentic shield, obscurely divided by two longitudinal impressions into three lobes, supporting the organs of vision on their highest part. The tergal parts of the segments of the second division of the body are also blended into one trilobate clypeiform piece, their original separation being indicated by the branchial fissures, and the number of the segments by that of the lamelliform appendages attached to their inferior surface. The termination of the intestine beneath the last segment of the second division of the body of the Limulus proves that division to answer to the abdomen in the Malacostraca: but admitting the sessile eyes to indicate a distinct segment, not more than sixteen segments can be determined by the appendages to enter into the composition of the entire crust of the Limulus, including the sword-shaped appendage, which is analogous to the last or post-anal segment of the higher Crustacea, and consists of a single modified segment.

In the small Entomostraca, the number of the thoracic and abdominal segments generally exceeds that in the Malacostraca. The *Branchipus stagnalis*, for example, has eleven thoracic segments, and nine abdominal or caudal rings, besides a distinct head protected by a cephalic shield. In the *Isaura*, in which this shield is developed, as in the *Cypris*, *Daphnia*, and other Entomostraca, to the extent, and in the form, of a bivalve shell, enveloping the whole body, the number of thoracic and abdominal segments exceeds twenty-four.

The distinction between the Entomostraca and Malacostraca in the number of the segments of the body is of the first importance in determining the affinities of the ancient extinct Crustacea, called Trilobites. These remarkable animals were almost the sole representatives of the present class in the periods which intervened between the deposition of the earliest fossiliferous strata to the end of the coal formation.* Neither antennæ nor feet appear to have been found in their remains: the structure of the tergal part only of their body-segments is yet known; but these are grouped together to form a distinct head, thorax, and abdomen or tail. The head is formed by a large semicircular or crescent-shaped shield; the thorax consists of from six (*Ampyx*, *Cryptolithus*), seven (*Ogygia*), eleven (*Phacops*), thirteen (*Calymene*), to fifteen segments: and the abdomen or tail includes at least eight segments in this *Calymene*†, in which it is bent under the thorax, as in the crab: the abdomen, post-abdomen, or tail, as the

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* Buckland, Bridgwater Treatise, i. p. 390.

† No. 208.

third segment is variously termed, contains fifteen fettered segments in the *Asaphus caudatus:* the segments of both thorax and abdomen are very similar to each other, and gradually decrease in size. They are divided by two longitudinal furrows into three lobes. The head usually supports a pair of large compound eyes situated near the sides, like the larger outer pair of eyes in the *Limulus*, which they resemble in form and structure.

The Malacostraca are divided into two groups, according to the attachment of the eyes: those with immoveable sessile eyes form the *Edriophthalma*, those with moveable pedunculated eyes the *Podophthalma*.

The lower organised or edriophthalmous forms of malacostracous Crustacea resemble the Trilobites in the non-confluence and uniformity of the segments of the thorax, and abdomen. Certain genera, as *Serolis* and *Bopyrus*, have the tergal arcs of the segments trilobed; but they exceed not the characteristic number in the Malacostraca, and the seven rings of the thorax are clearly indicated in each by the seven pairs of articulated feet which they support, although these are very small in the parasitic *Bopyrus*. In the *Cymothoa* (*fig.* 129) the seven thoracic and seven abdominal segments are more distinctly characterised.

The seven segments of the head are rather indicated by the appendages of that part than demonstrable in any of the Crustacea. The Stomapoda afford, in the genus *Squilla*, the most favourable examples for studying the conformation of the head. The first segment supports the pedunculated eyes: the second the smaller antennæ: the third and fourth segments are confluent, but indicated by the larger pair of antennæ and a pair of mandibles; the tergal part of these confluent segments is greatly developed, and extends over the rest of the head and part of the thorax. Three other pairs of jaws indicate the rest of the seven cephalic segments; and these are succeeded by the seven thoracic rings and their articulated appendages (*fig.* 128, A). Of these the first two pairs, which are organised for locomotion in the isopods and amphipods, are now modified to serve as jaws; and the remaining five pairs (ib. 3—7) are reserved for locomotion in all the podophthalmous Crustacea. In the Decapoda (Crabs, Lobsters,

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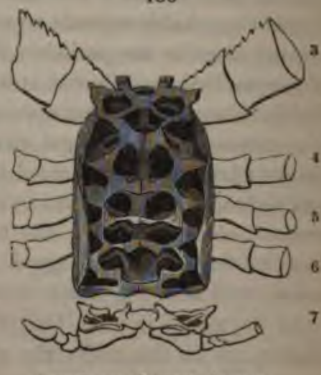

Sternal arcs of thorax, Astacus.

Prawns), the first of these five ambulatory thoracic legs is commonly the largest, and didactyle (*fig.* 130, 3). They all consist of six joints, called, as they recede from the trunk, *coxa*, *trochanter*, *femur*, *tibia*, *tarsus*, *metatarsus:* the latter is often prolonged into a sharp stiff claw; but, in the swimming crabs, it is flattened and expanded in certain legs: when modified as pincers, the *tarsus* is expanded and prolonged into a finger-shaped process, against which the last segment can be applied like a thumb. Each leg has usually two appendages attached to its base, called the palp and flagellum: analogous appendages are attached to most of the thoracic and cephalic articulated appendages, which subserve as jaws.

The tergal arc of the blended third and fourth cephalic segments extends over all the thoracic segments in the macrourous and brachyurous Crustacea, and constitutes the broad carapace in the crab. In most Macroura the thoracic shield is formed of the lateral or epimeral elements of the fourth cephalic ring, which meet along the back, and give way preparatory to the moult. The tergal elements of the thoracic rings are not developed in either crabs or lobsters; when these rings are exposed by lifting up the cephalo-thoracic shield, the epimeral parts alone are seen converging obliquely towards one another, but not joined at their apices. The thoracic legs, besides serving for mastication, prehension, and locomotion, usually support more or less of the branchial apparatus, and certain pairs are perforated by the generative ducts, except in the crabs, in which the broad sternal arc supports the generative outlets.

The sternal arcs of the thoracic segments (*fig.* 130) send inwards certain processes, called apodemata, which include spaces for protecting the abdominal nervous chords and the branchiæ, and which give origin to the muscles of the legs.

The seven abdominal segments are always united by flexible joints, and have no apodemata. In those Crustacea in which the thorax and its cephalic shield are small, the abdomen is long, as in the squillæ (*fig.* 128, A, 1—7, in outline), lobsters, and shrimps, and it characterises the great tribe of Podophthalma called *Macroura;* in those in which the thorax and its shield are greatly expanded, the abdomen is very short, as in the crabs, and it characterises the tribe hence called *Brachyura.* This alternating excess and arrest of development of the opposite divisions of the trunk well illustrate the law of organic equivalents.

In a small intermediate group, called *Anomoura*, including the *Paguridæ*, or Hermit-crabs, and the *Galatheidæ*, the abdomen presents intermediate proportions, and in some an anomalous structure: the fifth pair of ambulatory legs, e.g., is attached to the first abdominal ring, and is usually folded upon the back: it performs the office of sweeping the gills, the flabellæ, which have that function in the *Brachyura* and *Macroura*, being absent from the branchial chamber.

The appendages of the abdominal segments (*fig.* 128, 1—7) are developed, like those of the thoracic ones, from the inferior arcs: they are usually broad, flat, ciliated plates, which may sometimes aid in respiration, are more commonly organs for swimming, form a temporary place of attachment and protection to the ova, and are restricted to this use in the females of the Brachyura, in which the abdomen or tail is concealed by being bent forwards upon the sternum. In the hermit-crabs, which present an anomalous softness of their abdominal segments, the last pair of appendages form the claspers by which the parasite holds fast by the columella of the shell it may have selected for its abode.

The calcified integument of the Crustacea being inelastic, inextensile, and not endowed with inherent powers of growth; being likewise so disposed in the Podophthalma as to inclose and protect the greater part of the body by annular or large shield-like pieces like back- and breast-plates, must needs be thrown off to allow of the growth of the animal. This moult of the external integument has been observed in a few species of Crustacea, in the full-grown specimens of which it appears to take place annually; and a like ecdysis is probably common to all the class. Reaumur gave the first good account of the process in the craw-fish (*Astacus fluviatilis*). It takes place generally in the month of August. The animal previously retires to some place of concealment, is quiet and fasts for a few days, during which time the old crust is loosened from the lining membrane beneath, which becomes thickened, vascular, and like velvet. As this begins to harden, the animal takes measures to rid itself of its old crust; it rubs its legs against each other, throws itself upon its back, contracts and swells out the body, with alternate violent inflections and intervals of rest. The carapace is thus separated from the abdominal segments, is pushed upwards, and the animal liberates its head with the eyes and antennæ, which are provided with new sheaths: then the more difficult operation of freeing its extremities takes place: finally, the crawfish creeps out of the remainder of its old shell by withdrawing the abdominal segments; when the parts of the cast-off shell frequently return so nearly to their old positions as to represent the outward form of the animal with all its appendages, even the hairs and lining of the stomach. In one or two days the calcification of the new crust is completed, and the animal is restored to health and activity. During this period two very remarkable accumulations of calcareous matter, situated at the sides of the stomach, and known in the old pharmaceutical works as "Oculi Cancrorum," have disappeared: it would seem that the hardening material had been previously accumulated in readiness for the rapid calcification of the new crust, in order to reduce to the shortest period the defenceless state of the craw-fish after its moult.

The chief difficulty in accepting this account of the moult has been with regard to the possibility of the soft parts filling the expanded segments of the pincer-claws of the crab or lobster being withdrawn through the narrow apertures of those segments where they are joined together. But the whole muscular system of the moulting Crustacean is subject at that period to active absorption, which reduces it to about a third of what the cavity is capable of containing. A quantity of sea-water is introduced between the shrunken soft parts and the old hard shell. This interposed fluid stretches every part of the yielding walls of the joints, and facilitates the passage of the reduced muscular structure through the contracted apertures. The limbs are subject, in the act of extrication, to spasmodic twitchings; but, when a small portion of the soft claw has been thus withdrawn from the orifice, the rest follows almost without an effort.

In shedding the main part of the shell or carapace, the line of union round the sides and front, which passes between the eyes and mouth, and terminates on each side near the insertion of the hinder legs, is dissolved by absorption. 'The lining membrane of the old shell, which is the basis of the formation of the new, is reflected into each hard compartment lodging the muscular masses, and into the chambers for the stomach and other soft parts: by the changes it undergoes in the preparation for calcification it cuts off the former close connection of the included parts with the apodemata and manifold processes of the old complex shell. In the act of separation the crab has sometimes been seen to throw itself on its back, working the branchiæ with unusual force, and making the utmost effort to disengage the internal processes. It escapes at the fissure where the tail is connected with the carapace. Sometimes the crab hitches one of its claws into some crack or fissure, and from this point of resistance gains more power in emerging and withdrawing itself from between the carapace and tail. The parts of the old crust once evacuated, fall by the elasticity of their joints into their natural relative position: even the line around the carapace does not appear separated unless minutely examined; while the antennæ, palpi, eyes, complicated organs of the mouth, branchiæ, internal tendons, inner membrane of the stomach, with the gastric teeth, the double crustaceous body at the pyloric orifice, the two levers that proceed internally from the jaws to further triturate the food after it has undergone the maxillary mastication, together with the whole of the internal chambers of the crust, are left as entire as if dissected by a skilful anatomist.

When the common crab has thus emerged from its old shell, its first feeble effort is to creep to the friendly shelter of the nearest crevice. Its general appearance is that of a lump of dough, inclosed in a coloured membrane. Its growth, however, at this period is remarkably rapid.*

The elementary fibre of the voluntary muscles, in the Crustacea, is pale, semitransparent, but is transversely striated: the flat tendon-like body into which the strong peninform muscle of the lobster's claw is inserted is an internal process of the shell, and has a chitinous basis: all the seeming tendons are in like manner "apodemata," or internal processes, appertaining to the exoskeletal, not to the muscular, system. The muscles of the trunk-segments are usually rectilinear flattened masses: they are accumulated in great force in the long post-abdomen, or tail, of the lobster and other Macroura: here the flexors are on the ventral, the extensors on the dorsal surface, the former being the largest and most powerful. They usually pass from one segment to the next; mostly with a longitudinal course, a few being oblique and decussating. In the little Cypris, some muscular fibres arising from the back of the animal act like adductor muscles on the bivalve shell.

The Crustaceous Homogangliata are not less remarkable for the different conditions of their nervous system, arising out of the progressive concentration of its central masses, than for the diversity of their outward forms. Even in the higher, or Malacostracous division, a very extensive series of modifications are presented, which lead from the Anellidous to the Brachyurous type, or that of the crab.

In the lowest worm-like, equal-footed, and equal-ringed Crustacea, the dermal skeleton has become sufficiently firm and resisting to enable the trunk to be raised by the articulated members above the ground. The muscular system attains a proportionate increase of volume and force: so that when we contrast the conditions of the sensitive integument and of the motor system in these Crustacea with those of the same systems in the Anellids, we obtain most instructive tests of the worth of that hypothesis which ascribes sensation exclusively to the ganglions, and the motive energy to the

* CCXXXIII. p. 8.

non-ganglionic nervous columns of the *Articulata.* The same hypothesis will be more severely tried by the comparative anatomy of the nervous system in the higher species of the Crustacea, on account of the varying conditions as to sensation and motion which different parts of their more diversified forms of body present.

We find in the lowest Isopoda, as the woodlouse (*Oniscus*) and the sandhopper (*Talitrus*), that the supposed sensitive organs, the ganglions of the abdominal chords, are more developed than in the highest Anellides: they are likewise more distinctly bilobed; each lateral chord presenting its own ganglionic enlargements, which are in juxtaposition, but not confluent, so that there is a distinct pair of ganglia for each segment. If these ganglions be microscopically examined, they present, as their essential structure, large round or pyriform cells with a large nucleolated nucleus; and three orders of nervous filaments may be perceived in them. The first is longitudinal, and extends over the dorsal aspect of the ganglia; the second is also longitudinal, and originates from, or terminates in, the ganglia; the third is transverse: these fibres pass round the ganglionic cells, and emerge laterally: they, in *Talitrus*, connect the two ganglions of each pair with each other, and in all Crustacea form the transverse or peripheral nerves. *Talitrus* presents ten pairs of nearly equidistant sub-abdominal ganglions, the two first and the two last being most approximated. In *Cymothoa* (*fig.* 129.), a species in which the tapering terminal segments of the body have begun to be concentrated by longitudinal approximation, the corresponding nervous ganglions at the posterior part of the abdominal chord present a corresponding change, advancing forwards like the caudal part of the spinal column in the metamorphosed larva of the frog.

In the higher Crustacea, with a thorax covered by the cephalic shield, and supporting disproportionately large and prehensile anterior extremities, the thoracic ganglia exhibit proportionate increase of size, with a tendency to unite, or with actual confluence. The ganglions of each lateral abdominal chord have now more completely coalesced by transverse approximation. In *Squilla mantis*, the super-œsophageal ganglion or brain sends off five nerves on each side, those to the long antennæ being recurrent in their course. Stomatogastric nerves arise from the œsophageal chords, which unite below into a long sub-œsophageal ganglion, apparently formed by a confluence of three originally distinct pairs. This is succeeded by three other ganglions in the thorax, supplying three pairs of thoracic legs; and there are six ganglions in the muscular tail. The œsophageal chords are unusually long and slender in the transparent Phyllosoma.

The neurology of the Crustacea has been most completely illustrated in those species which are covered by a dense insensible crust. Succow, in 1818, and Brandt, in 1833, published excellent descriptions of the nervous system of *Astacus fluviatilis* (*fig.* 3. p. 13.). The cephalic ganglion sends branches to the eyes, to the large and small antennæ, to the antennal sheaths, and to the organs of hearing. A nearly straight chord is continued from this ganglion, on each side of the œsophagus, to the first of the sub-abdominal series. An azygous nerve arises from the middle of the posterior surface of the cephalic ganglion, and passes backwards to the stomach, where it communicates with two nerves given off one from each of the œsophageal chords to supply the stomach. The sub-œsophageal ganglion distributes nerves to the masticatory organs and to the pharynx, just as the medulla oblongata sends off the fifth pair and glosso-pharyngeal in the vertebrate animals. The second to the sixth thoracic ganglia inclusive supply the feet and gills with nervous influence; the generative organs receive long filaments from the fourth, the fifth, and the sixth thoracic ganglions. The ventral or sternal artery, descending from the heart, passes between the nervous columns at the interspace between the fourth and fifth ganglions. Six ganglions are developed on the abdominal chords, which are continued along the muscular tail: the last, which is above the anus, is the largest, and radiates the nerves to the terminal swimming plates of the tail. This is probably a coalescence of the originally distinct ganglions of the sixth and seventh segments of the abdomen or tail.

The nervous system of the lobster is well displayed in dissections by John Hunter[*], and has been beautifully illustrated by Mr. Swan.[†] The nerves of the lobster closely correspond with those of the fresh-water species, or craw-fish. The non-ganglionic tracts are shown in a dissection of the lobster by Mr. Newport[‡]; but the distinctions of the origins of the nerves from the dorsal and the ventral tracts are, as Mr. Swan remarks, by no means clear. The œsophageal columns are united in both species of *Astacus* by a transverse commissural chord.

In the prawn (*Palemon*) and rock-lobster (*Palinurus*), the thoracic ganglia coalesce to form a long, elliptical, perforated nervous mass. In the hermit-crab (*Pagurus*)[§], the cephalic ganglion presents a transversely quadrate form, and sends off the usual nerves to the eyes, the ears, and the antennæ. The lateral œsophageal chords, after supplying the digestive system with the stomato-gastric nerves, unite below to form the ganglion which distributes nerves to the maxillary apparatus and pharynx. This is succeeded by a large oblong ganglion, situated at the base of the great nippers, and of the second pair of feet, both of which pairs it supplies. The lateral chords diverge for the passage of the artery, re-unite to form a third thoracic ganglion, smaller than the second, supplying the third pair of thoracic legs, and sending off three pairs of nerves posteriorly. Of these the lateral pair goes to the fourth diminutive pair of feet; the median pair supplies the fifth pair of feet: the two remaining dorsal nerves, which are of minute size, form the continuations of the abdominal chords, and pass along the under or concave side of the soft, membranous, and highly sensitive abdomen to the anus, anterior to which the last small ganglion is situated: this supplies the nerves to the muscles of the caudal plates, here converted into claspers, and enabling the animal to adhere to the columella of the univalve shell, which it may have selected to protect that portion of its body which nature has left undefended by the usual dense and insensible crustaceous covering.

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[*] Preps. Nos. 1301, 1302, 1303, described in X. vol. iii. p. 15.

[†] CCXXXIV. Part I. pl. 3. and 4.

[‡] Prep. No. 1302, A.

[§] Prep. No. 1303. B.

Experiments have been made, and repeated, in order to determine whether the ganglionic portions of the abdominal chords of the *Articulata* have the same restricted function which the posterior roots of the spinal nerves in the *Vertebrata* have been proved to possess. With respect to the anatomical grounds which were first adduced in proof of this correspondence of function, they are invalidated by the fact that the presence of ganglions in the sensitive roots of the spinal nerves is not their constant character.

The results of the experiments alluded to, though somewhat contradictory, are, upon the whole, as might have been anticipated, hostile to the conclusions founded upon a partial anatomical analogy. A more extended investigation of the Comparative Anatomy of the Nervous System has remedied the imperfection of the experimental inquiry, has supplied the answers which were in vain attempted to be gained by mutilating the living Crustacea, and has brought the hypothesis in question to the test of deductions which may be legitimately drawn from those surer experiments which Nature herself has left for our instruction in the modification of the crustaceous type of structure. We have here* two opposite conditions of a large and important part of the trunk of two nearly allied Crustacea. In the lobster (*Astacus*) the abdomen or tail is encased in a series of calcareous rings, forming a hard and insensible chain armour: but in the same degree

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* Preps. No. 1301. and 1303. B.

as sensibility is lost, motility is acquired; a great proportion of
muscular system of the animal is concentrated in the tail, w
forms its most powerful and almost exclusive organ of swimn
In the hermit-crab (*Pagurus*), on the other hand, the muscular sy
is almost abrogated in the long abdomen; for this, in fact, take
share in the locomotive functions of the body: it is occupied by
of the alimentary canal, and by glandular organs: the sensibilit
the external integument is not impaired or destroyed by the de
tion of calcareous particles in its tissue; but it retains the neces
faculty of testing the smooth and unirritating condition of the i
surface of the deserted shell, which the animal chooses for its ab
minute acetabula are developed in groups upon this sensitive
tegument[*], to which, also, delicate ciliated processes are attac
The muscular system is reduced to a few minute fasciculi of fi
regulating the action of the small terminal claspers. Now, if, as
been conjectured, the ganglionic enlargements of the abdon
chords monopolize the sensorial functions, and the non-gangli
tracts the motor powers, we ought to find the nerves, which su
the muscles of a tail constructed almost exclusively for locomotio
be derived from non-ganglionic columns; whilst in the tail, whi
almost as exclusively sensitive, the ganglions ought to have been l
and numerous, for the supply of nerves to the integument.
contrary, however, is the fact; six well developed ganglions
tribute nerves to the muscular fibres of the lobster's tail; non-
glionic columns supply the sensitive tail of the hermit-crab.
ganglion, indeed, is present in the Pagurus, but both its situ
and office alike militate against the hypothesis of its special sul
viency to sensation: it is developed upon the end of the smootl
dominal chords, and seems to have been called into existence s
to regulate the actions of the muscles of the terminal clasper
which the hermit keeps firm hold of the central pillar of his
rowed cell.

The general progress of the development of the nervous syste
the Crustacea has been, as we have seen, attended with incre
size, and diminished numbers of its central or ganglionic ma
The divisions of each pair of ganglia first coalesce by trans
approximation: distinct pairs of ganglia approximate longitudin
conjoining as usual from behind forwards: confluent group
ganglia are next found in definite parts of the body, as on the th
of those species which have special developments and uses for
ticular legs. In the crab, in which the general form of the

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[*] Broderip, Zool. Journ. vol. iv. p. 200.

attains most compactness (*fig.* 131.), the ventral nervous trunks are concentrated into one large oval ganglion (*g*), from which the nerves radiate to all parts of the trunk, the legs, and the short tail.

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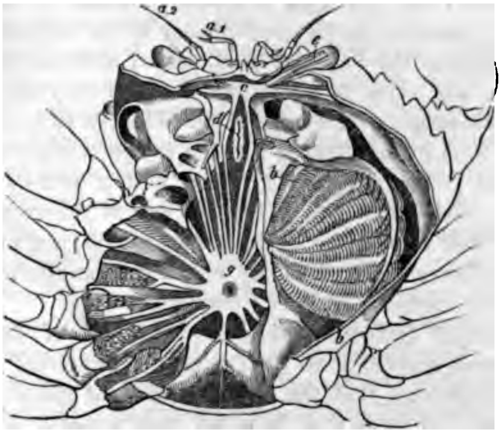

This condition of the nervous system has been described by Cuvier in the common crab, and is illustrated by Mr. Swan's dissections, from which his beautiful plates have been taken.* The corresponding structure of the nervous system is also well displayed by Audouin and Edwards in *Maia.* An analogous concentration, but not a homologous one, obtains in *Limulus.* Here the nervous substance is chiefly massed round the œsophagus, the fore part of the ring expanding into a pair of ganglions from which the nerves are sent off to the small median and large lateral eyes: the nerves to the latter are of great length, wind round the anterior apodemata, and bend back to their termination, breaking up into a fasciculus of minute filaments before penetrating the large compound eye. Two stomatogastric nerves arise from the upper and fore part of the ring. From the under surface of the fore part of the ring, a small pair of nerves pass to the first short pair of forcipated jaw-feet: five large nerves proceed from each side of the ring to the five succeeding jaw-feet. A pair of slender nerves pass to the spiny-edged lamelliform appendage. The posterior part of the nervous ring is prolonged backwards in the form of a chord, having four ganglionic enlargements on its ventral surface, and terminates opposite the penultimate postabdominal plate in a fifth slight ganglionic enlargement which bifurcates: each division sends off a few nerves as it proceeds to the caudal appendage, on entering which, it is resolved into a plexus or kind of "cauda equina." Besides the principal nerves above mentioned, many smaller nerves are given off to other parts of the body. The sides of the great œsophageal ring are united by two transverse commissural bands: but the most remarkable feature of the nervous axis of this Crustacean is its envelopment by an arterial trunk. A pair of aortæ from the fore part of the heart arch over each side of the stomach, and seem to terminate by intimately blending with the sides of the œsophageal nervous ring. They, in fact, expand upon, and seem to form its neurilemma; a fine injection thrown into them coats the whole central mass of the nervous system with its red colour. Such is the condition of this governing part of the organisation in the most gigantic form of the Entomostracous tribe, and probably the only existing genus from which we may derive an insight into the structure of the extinct Trilobitic Crustaceans.

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* CCXXXIV. Part I. pl. 1. and 2.

Three principal divisions of the nervous system of the Crustacea may be defined according to their probable functions. Thus, admitting, from analogy, that the super-œsophageal ganglionic centre (*figs.* 129. and 131. *c*) is that in which true sensation and volition reside, then those nervous filaments which are exclusively connected therewith, and some of which would seem to extend the whole length of the animal along the dorsal aspect of the ganglionic columns, will form with their ganglionic centre the true sensori-volitional system; whilst any other ganglions superadded to the abdominal columns, with the nervous filaments terminating in or originating from them, will constitute the system for the automatic reception and reflection of stimuli. The stomato-gastric nerves, connected partly with the brain and partly with the œsophageal columns, will form a third system analogous to the great sympathetic or organic nerves of the Vertebrata. In these views I coincide with the accomplished physiologist, Dr. Carpenter, believing that their accuracy and soundness have received confirmation from the facts of Comparative Anatomy, described in the previous pages, and which, in the Hunterian Lectures of 1842, were for the first time brought to bear upon this interesting problem.

The sense of touch can be but very feebly exercised by the common integument of the Crustacea, can hardly, indeed, exist except in those parts of the surface of the body which remain soft and undefended by the hard crust, such as the joints of the under part of the body, and the surface of the soft tail in the hermit crabs. The fine hairs which project from many parts of the integument may compensate for its low endowment of the tactile sense: the two pairs of jointed antennæ (*figs.* 128. 131. *a*) are instruments fitted for the most delicate exploration; and the smaller but similar organs attached to the jaws, and called palpi, may also receive some impressions analogous to those of savour or smell. The Crustacea have no true tongue, but the sensations of the membrane lining the interior of the mouth and the œsophagus may guide them in the selection which they make of objects of food.

The sense of smell is referred to a shallow excavation in the basal joint of the first or median antenna, which opens by a fissure fringed by fine hairs on the upper surface of the joint: this cavity is lined by a soft membrane, supplied by a branch of the internal antennal nerve. The organ is well described and figured in CCXXXV., pl. 9. and 10., in which memoir the author calls attention to the presence of minute grains of sand; and these, although they must enter accidentally into the cavity, he suggests may act as otolites, surmising the cavities in the small antennæ to be acoustic organs.

The sense of hearing is referred by most authors to a conical process containing a cavity with a round orifice closed by a membrane, proceeding from the first joint of the second (external and larger) pair of antennæ, in the lobster and other Macroura. Behind the process there is continued from its cavity a large sac filled with a clear liquor: a nerve arising in common with the external antennal nerve is spread upon the delicate walls of the supposed acoustic sac. In most of the Brachyura the membrane is stated by Dr. Edwards to be replaced by a small moveable calcareous disc, which is pierced with a small oval opening, over which there is stretched a thin and elastic membrane. The external opening of the ear is closed by this bony disc. A second small plate is so situated as to regulate the tension of the auditory membrane, whilst the rigid stem of the antennæ, in which the whole organ is situated, is well adapted to render the auditory vibrations more distinctly perceptible. These vibrations are conveyed through the medium of a vesicle filled with fluid to a branch of the antennal nerve which expands in the vesicle.

In both the lobster and crab a tube, filled by a greenish substance, is concealed in the lower portion of the shell, and communicates, or is in close contact with, the membranous sac. This structure, and the absence of otolites, has led Farre to suggest that the organ may be olfactory: but the chief parts of the structure bear a close correspondence with an auditive vesicle and a tympanitic membrane.

With respect to the organ of vision, we find in the class Crustacea a most extensive and interesting series of gradations, leading from the simple sessile median eye-speck to two distinct eyes, provided with all the essential optical apparatus and placed upon moveable peduncles. Ocelli or stemmata are combined with compound eyes in the same species in certain Entomostracans, as *Apus* and *Limulus*. A transparent speck of the integument forms the cornea of the ocellus, immediately behind which there is a spherical crystalline body in contact with a gelatinous or vitreous humour, upon which the extremity of the optic nerve expands: a layer of dark pigmentum covers all these parts with the exception of the cornea. In the compound eyes of *Daphnia*, the smooth undivided cornea protects and transmits the rays of light to an aggregation of small ocelli, each of which is lodged in a pigmental cell: the similarly constructed compound eye of the active little *Branchipus* is supported on a short moveable peduncle.

The large lateral compound eyes of the Limulus are sessile: the cornea is divided into a considerable number of small circular facets, each of which corresponds to an ocellus; and the optic nerve, after its long course as a simple chord, divides near the eye into a pencil of fine filaments, which severally receive the impressions from their respective ocelli, of the aggregate of which the large lateral eye is composed. The two small simple median eyes, which are almost in contact, command the space before the head, which is out of the range of the large compound eyes: each simple eye receives its distinct nerve from the anterior apex of the corresponding cerebral lobe.

In some of the Trilobites, the cornea presents the same subdivided surface as in the Limulus; and the position of the two eyes agrees with that of the corresponding compound pair in the large existing Entomostracan. The eyes are more elevated in some of the Trilobites, as *Phacops*. In *Asaphus caudatus* the cornea is divided into at least 400 compartments, each supporting a circular prominence: its general form is that of the frustum of a cone incomplete towards the middle line of the head, but commanding so much of the horizon in other directions, that where the distinct vision of one eye ceases, that of the other begins.

In certain *Phyllopoda* and *Amphipoda* a common cornea covers numerous closely aggregated simple eyes, consisting each of a pyriform lens, the apex of which is sunk in a black or brown pigment. The optic nerve, before reaching the pigment, divides into as many branches as there are lenses. In the sessile eyes of other *Edriophthalma*, as, for example, in *Serolis*, the inner layer of the cornea is divided into hexagonal facets, corresponding with the number of the conical crystalline lenses of the aggregate eyes. In *Amphithoë* this has been regarded as a second distinct cornea.

In the mandibulate Crustaceans, distinguished by having their compound eyes supported on moveable peduncles, the form of the corneal facets varies; they are square in the lobster and river craw-fish, hexagonal in the hermit and common crabs. There is a conical crystalline lens behind each facet imbedded in a small vitreous humour, upon which the optic filament expands, and each ocellus is lodged in a pigmental cell, which likewise covers the bulb of the optic nerve; the cavity containing the compound eye is closed behind by a membrane continuous with the inner layer of epiderm, and pierced for the passage of the optic nerve (*fig.* 131. *e*). In the podophthalmous Crustacea there is generally a spacious furrow or cavity, in which the eye and its peduncle can be lodged and protected, and it is termed the orbit. In one or two species, e. g. *Gelasimus telescopicus*, the eye-stalks project beyond the margins of the carapace.*

One of the most valuable and interesting results of the study of the comparative anatomy of the eye in the Crustacea is the insight which the fossilised remains of similarly constructed organs of vision in the extinct Crustacea have given into the state of the world at the time when they existed; and I cannot better conclude the present discourse than in the eloquent language of the geologist who first taught the value of the evidence in question. The eyes of the Trilobites of the transition rocks, and those of their nearest congeners, the fossil Limuli from the Carboniferous series, "give information," says Dr. Buckland, "regarding the condition of the ancient sea and ancient atmosphere, and the relations of both these media to light, at the remote period when the earliest marine animals were furnished with instruments of vision in which the minute optical adaptations were the same that impart the perception of light to Crustaceans now living at the bottom of the sea.

"With respect to the waters wherein the Trilobites maintained their existence throughout the entire period of the transition formation, we conclude that they could not have been that imaginary turbid and compound chaotic fluid, from the precipitates of which some geologists have supposed the materials of the surface of the earth to be derived; because the structure of the eyes of these animals is such, that any kind of fluid in which they could have been sufficient at the bottom, must have been pure and transparent enough to allow the passage of light to organs of vision, the nature of which is so fully disclosed by the state of perfection in which they are preserved. With regard to the atmosphere, also, we infer that had it differed materially from its actual condition, it might have so far affected the rays of light, that a corresponding difference from the eyes of existing Crustaceans would have been found in the organs on which the impressions of such rays were then received.

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* CCXXXVI., p. 78., pl. xxiv. fig. 1.

"Regarding light itself, also, we learn, from the resemblance of these most ancient organisations to existing eyes, that the mutual relations of light to the eye, and of the eye to light, were the same at the time when Crustaceans, endowed with the faculty of vision, were first placed at the bottom of the primeval seas, as at the present moment.

"Thus we find among the earliest organic remains, an optical instrument of most curious construction, adapted to produce vision of a peculiar kind, in the then existing representatives of one great class in the articulated division of the Animal Kingdom. We do not find this instrument passing onwards, as it were, through a series of experimental changes from more simple into more complex forms; it was created at the very first, in the fulness of perfect adaptation to the uses and condition of the class of creatures to which this kind of eye has ever been, and is still, appropriate."

LECTURE XV.

CRUSTACEA.

The Limuli, which form the only genus of large Crustaceans represented by species which co-existed with the Trilobites, differ from all other living Crustacea in their organs of mastication, which are the modified basal joints of the five posterior pairs of legs: the first small pair serve to bring the objects of food to the mouth; they are supported on a rudimental labrum, and have their basal joint subtrenchant, if working from before backward. The basal joints of the four following pairs are beset with spines, and act as "carders:" that of the sixth pair is hard, subtrenchant, and works from behind forward: a pair of subquadrate compressed plates, with spiny borders, working in the same direction and closing the mouth below, may represent a rudimental seventh pair of limbs, or a divided labium. In *Asaphus platycephalus* Mr. Stokes[*] discovered a distinct subquadrate labrum deeply emarginate anteriorly; the nearest approach to this, the only known part of the trophi of the Trilobites, seems to be made by the entomostracous genus *Apus*, in which, however, the labrum is truncated. A few of the lowest organised *Crustacea*, as *Caligus*, *Nymphon*, and *Pycnogonon*, obtain their aliment, like the *Epizoa*, by suction.

[*] Geol. Trans. N. S. vol. i. pl. 27.

In the malacostracous Crustacea the mouth is closed by a small and simple membranous labrum above, by a bifid labium below, and by a pair of mandibles and maxilles at the sides; the mandibles are the legs or jointed appendages of the fourth cephalic segment; the maxilles are the same appendages of the fifth. The mandibles are worked by large muscles arising from the cephalo-thorax: their internal border is hard and often toothed; they support palpi. The maxilles are weaker, softer, and without palpi. In the common crab you will observe behind and exterior to the maxilles a third pair of jaws, which have their principal part terminated by a cutting edge, and are without palpi: the two following pairs of jaws are distinguished by their articulated feeler or palp and by their flabelliform appendages, which penetrate into the interior of the branchial cavity; the maxillary plate is armed with teeth; the sixth and last pair of jaws has the maxillary plate so much expanded as to cover and protect the whole oral apparatus: it has likewise a palp and flagellum articulated to its base. All the foregoing maxillary organs are modifications of entire limbs, which are thereby translated from the locomotive series: the jointed legs so metamorphosed belong to the last four cephalic, and the first two thoracic, segments.

The alimentary canal is most simple in the suctorial Crustacea, in which it presents no noticeable difference from that in the Epizoa; the hepatic appendages are however more localised and better developed.

In the Limulus the mouth is situated nearly in the centre of the inferior surface of the great cephalo-thoracic segment; the œsophagus is continued from it in a very unusual course forwards, and expands into a stomach, which is situated at the anterior part of the head. This organ is abruptly bent upon itself upwards and backwards, and is continued by a gradual diminution of diameter, as appears upon an external view, into the intestine, which passes backwards with a slight vertical bend to the base of the penultimate abdominal segment. When we examine the interior of the alimentary tract, the distinction between the stomach and intestine is effected, as Van der Hoeven has shown, by a conical valvular pylorus, which projects into the commencement of the intestine. The stomach is lined by a very dense and corrugated horny membrane. The hepatic mass, composed of contorted slender cæca, which, with the generative glands, fills the greater part of the cephalo-thoracic cavity and also extends into the abdomen, pours its secretion into the commencement of the intestine by two ducts on each side.*

Amongst the smaller Entomostraca *Lynceus* departs most from the common simple type of the intestine in Crustacea, by having that canal disposed in one or two spiral coils. In the Stomapods or Squillæ the stomach bends forwards in advance of the cardiac orifice; a bi-articulate plate extends from that orifice backwards through the pylorus into the intestine, and regulates the passage of the alimentary substances into that tube; they are previously subjected to the action of four lateral dentated pyloric processes.

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* Prep. No. 477. A.

In the higher Crustacea the stomach (*fig.* 132, *c*) is of a globular form, more capacious than in the *Limulus*, and its walls are connected with a calcareous frame-work supporting dense tubercles, which project into the interior of the stomach around the pylorus, and are so situated and moved with relation to each other as to divide and bruise the alimentary matters before they pass into the intestine. In the common lobster these gastric teeth are three in number, the middle one serving as a kind of anvil upon which the two larger lateral pieces work.* This complex kind of gizzard is sometimes found to be everted and protruded from the mouth, the gastric teeth being then external, like those of the anterior muscular segment or proboscis of the alimentary canal in the Anellides. The inner tunic of the stomach is composed of chitine, and is beset with groups of hair-like processes in most Decapoda.

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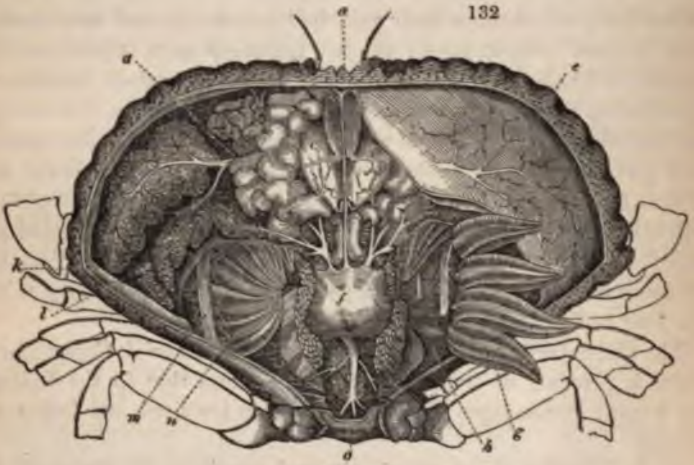

Cancer pagurus.

The intestine in almost all Crustacea is continued to the vent without convolutions; a terminal portion, or rectum, is sometimes, as in the lobster, indicated by a slight circular valve; the vent is situated

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* Preps. Nos. 407, 408.

beneath the terminal segment of the abdomen, anterior to its appended swimming plates in the Macroura, which would indicate that the long sword-shaped appendage of the Xiphosura was not the homologue of the post-abdomen, but of its last joint in the Macroura.

The liver is a considerable organ in all the Crustacea; it makes its appearance in the inferior species as so many cæcal prolongations of the intestine, continued from many points, according to the primitive form which it presents in the Aphrodita. The biliary cæca extend even into the limbs in the Nymphons. In the Stomapods the biliary cæca, continued ten or eleven in number at equidistant points from each side of the intestine, are more ramified, and are confined to the thoracic-abdominal cavity, where they penetrate the interspaces of the muscles.*

In the Decapod Crustacea the liver (*fig.* 132, *l*) consists of two symmetrical halves, communicating by distinct ducts with the intestine; each half consists of numerous lobes, which, in the larger Macroura and Brachyura, are leaf-shaped, and composed of straight tubular cæca, arranged obliquely to a median canal, which forms, as it were, the leaf-stalk. In some species one or two pairs of long slender and simple tubuli likewise communicate with the intestine. The bile is acid in the Crawfish (*Astacus fluviatilis*).

In many Crustacea the digestive canal is surrounded by cells filled by an oily or fatty matter of a yellow or blue colour: they may be compared to an omentum, and probably serve as a store of nutriment, to be drawn upon during the moult, or when food is scarce.

No other vessels are yet known to convey the chyle or nutrient fluid to the circulating system than the irregular venous receptacles which are in contact with the parietes of the intestine. Almost the whole venous system presents the form of wide flattened sinuses, and offers an intermediate condition between that in the Nereids and the generally diffused state of the venous blood through all the cellular interspaces of the body in the class of insects. Through these sinuses, however, the blood flows in a constant and definite course.

The numerous experiments of Audouin and Milne Edwards† on the circulation of the Crustacea, and the apparently favourable circumstances under which they were made, have very generally been regarded as conclusive of the accuracy of their explanation of that important function in the present class. According to these physiologists no other than the two great branchial veins terminate in the heart, and, consequently, only pure aërated or arterial blood is propelled by it over the general system: the circulation is the same as in the Gasteropodous Mollusca: the ventricle is exclusively systemic, and is provided with only two venous apertures. Four such apertures are described and figured by Dr. Lund on the dorsal surface of the heart, but these are regarded by Audouin and Edwards as depressions merely between the muscular fasciculi, having no communication with the ventricular cavity.

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* Duvernoy, Annales des Sciences, vi. p. 243.

† Hist. Nat. des Crustacés. 1829.

I have tested the conflicting evidence of these observers by dissection of the heart in the lobster; and you will perceive by this preparation[*] that it is more complicated than even the Danish Naturalist supposed, and fully bears out the opinion of Hunter in regard to the mixed nature of the circulation in the Crustacea.

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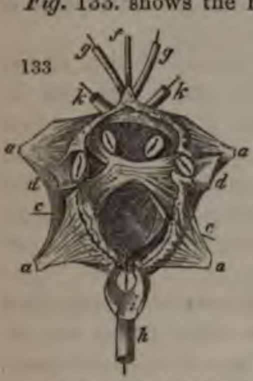

Astacus marinus.

Fig. 133. shows the heart laid open on the ventral aspect; by exposing its cavity from this side, it was readily determined whether the exterior depression on the dorsal surface did or did not lead into the cavity. On either side of the anterior depression from which the ophthalmic (*f*) and the antennal (*g*) arteries arise, there is a large oblique fissure, guarded by a pair of semilunar valves. The vein, which terminates by each of these orifices, is an extended, irregular, and extremely flattened sinus, lying above the heart, and between it and the lining membrane of the shell, communicating anteriorly with a similar broad irregular flattened sinus, which occupies a similar situation above the stomach, and receiving posteriorly the blood from a series of flat and expanded sinuses which correspond to each segment of the tail. There are two similar openings at the sides of the ventricle, posterior to the preceding, which conduct the blood from lateral sinuses into the heart: these orifices, indicated by the bristles (*c*, *c*), have each a pair of semilunar valves. The arterial blood, returned from the branchiæ, enters the heart by the large orifices on the sides of the ventral aspect (*d*, *d*), regurgitation being likewise prevented by two semilunar valves at each orifice. The muscular fasciculi of the ventricle are so arranged as to leave tolerably distinct chambers for each series of arterial orifices. The strongest bands or columns are transverse, and dorsad of the branchial apertures: anterior to these is a chamber receiving the carbonized blood from the two anterior dorsal apertures; it is partially divided, the upper chamber giving off (*f*) the ophthalmic, and (*g*) the antennal arteries. The lower chamber sends off (*k*, *k*) the hepatic arteries. The larger posterior chamber receives the two lateral venous apertures, and gives off (*h*) the superior caudal artery, and (*i*) the sternal artery, which is the chief vessel, and the only one which has a pair of semilunar valves at its origin.

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[*] No. 898. A.

A portion only of the ordinary venous blood is returned directly by the four valvular orifices just described. The blood is returned from the maxillæ and legs to a series of inferior lateral sinuses at the bases of the branchiæ; from these sinuses it passes, by vessels performing the office of branchial arteries, along the outer margin of the gill, and after being distributed over the branchial lamellæ, is collected into the vein along the inner margin of the gill, and by the union of the branchial veins into one trunk, on each side, is poured into the ventricle by the two orifices on its under surface (*d*, *d*).

We may trace in the heart of the Crustacea a gradational series of forms, from the elongated median dorsal vessel of the Limulus, to the short, broad, and compact muscular ventricle in the lobster and the crab (*fig.* 132, *f*). In all the Crustacea, as in all the other articulate animals, the heart is situated immediately beneath the skin of the back, above the intestinal tube, and is retained *in situ* by lateral pyramidal muscles (*fig.* 133, *a*, *a*). In the Entomostraca, and in the lower, elongated, slender, many-jointed species of the Edriophthalmous Crustacea, the heart presents its vasiform character: it is broadest and most compact in the crab.

In this series we may trace a general correspondence in the progressive development of the vascular as of the nervous system, concomitant with the concentration of the external segments, and the progressive compactness in the form of the entire body. But there is a remarkable exception to this concomitant progress in the Limulus, indicative, with the general condition of the instruments of locomotion and respiration, of the essentially inferior grade of organisation of that genus, which, as has already been observed, seems to be the last remnant of the once extensive group of Trilobitic Crustacea, which swarmed in the seas of the ancient secondary periods of the earth's history.

We have seen in the compact and broad existing representative of those extinct gigantic Entomostracans, that the nervous system exhibits a concentration of its principal central mass around the mouth, but with a ganglionic double cord continuing from it. The heart, however, is far from presenting a corresponding degree of concentration; it remains an elongated fusiform tube, extending parallel with the intestine from the pylorus to the rectum, like that of the *Squillæ*: in *Limulus*, it is contained in a pericardium with thin membranous walls, formed by the central sinus of the venous system, and it receives the blood from that sinus and from the branchial veins by a series of from seven to ten lateral vertical slits, defended by valves as in the higher Crustacea.* An aortic trunk proceeds from each extremity of this heart. The anterior aorta is the largest, and immediately divides into three branches. The middle and smallest branch passes forwards to the anterior edge of the cephalic shield, following the curve of its middle line, and supplying the small median ocelli in its course. The two larger lateral branches form arches which curve down the side of the stomach and the œsophagus, giving branches to both those parts and to the intestine, and becoming intimately united with the neurilemma of the œsophageal nervous collar. They unite at the posterior part of that collar, and form a single vessel, which accompanies the abdominal nervous ganglionic chord to its posterior bifurcation, where the vessel again divides. Throughout all this course the arterial is so closely connected with the nervous system as to be scarcely separable or distinguishable from it. The branches of the arterial and nervous trunks which accompany each other may be defined and studied apart. The posterior aorta is chiefly destined for the supply of the sword-like tail of the Limulus: the first part of its course is wavy, to adapt it to the strong inflections of that appendage. The aërated is mixed with the venous blood in the heart, and is propelled in that mixed condition throughout the body in the Limulus, as in the lobster.

The respiratory organs in the Crustacea are essentially appendages to the basal articulations of a certain number of the feet, and are originally developed from the flabelliform appendage, although they ultimately become entirely distinct from the extremities in the higher Crustacea.

The *Branchiopods* are so called because their fins or feet present the form of simple plates or flattened vesicles, which float in the surrounding fluid, and expose the blood to the oxygen which the water contains. The branchia are appended to the thoracic limbs, in the form of membranous plates, in the *Amphipoda;* and to the abdominal limbs, as subdivided lamellæ, in the *Isopoda:* the branchial plates expand into vesicles attached to the thoracic feet in the *Læmodipoda*. In the *Stomapoda,* the respiratory plates are also external, and are appendages of distinct locomotive organs, and each plate is divided into a series of small filaments or tubes; so as to resemble a broad feather: their position is abdominal. Similarly formed external gills are appended to the thoracic segments in the *Thysanopoda*.

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* Van der Hoeven, loc. cit. pl. 2. fig. 9.

In *Limulus* the two outer thirds of the posterior surface of the basilar joint of the abdominal prolegs are occupied by a great gill formed of a number (130—150) of folds of skin, disposed transversely and piled on one another like the leaves of a book: they adhere throughout the length of their base or anterior border, are elsewhere free, are semicircular or triangular, with curved borders, and increase in size from the upper end of the branchia to its base, so as to give this last the form of a pyramid. The free edge of each leaf is rounded, and furnished with a horny band destined to sustain it, and fringed with cilia: elsewhere the gill is membranous.

In the lobster and crab tribes the branchiæ are protected by the carapace, and are lodged in lateral recesses (*fig.* 132, *h*) formed by the apodemata of the thoracic segments. These branchial recesses are parts of a common cavity, lined by an internal fold of the tegumentary membrane, and having two apertures of communication with the surrounding medium. The posterior aperture lets in the water, which, traversing the branchial cavity, escapes by the one in front. In the crabs the entry is a cleft in front of the base of the chelæ or forceps-claw, and is so placed in reference to the prolonged base of that limb as to be closed or opened at the will of the animal. In the lobster and other Macroura, the entry to the branchial chamber is an extended fissure. The efferent passage from the branchial cavity passes over the lateral portions of the palate or prelabial area. In the *Leucosia* group it passes over the median portion of the palate.

The dynamical part of the respiratory functions is performed by the lamelliform appendages of the second pair of jaws, which are so situated in regard to the outlets of the branchial chambers as to drive out a certain quantity of the water which has been admitted into the chamber.* The loss of the foul water necessitates the entry of fresh water by the inferent orifices; the respiratory cavity being neither capable of expansion nor contraction. The mode of breathing in the crypto-branchiate or decapod Crustacea is thus the reverse of that in the Batrachia, in which the dynamical mechanism serves only to draw in the respiratory medium in successive quantities. In the higher vertebrata the thorax is so constructed as to execute acts both of inspiration and expiration.

The branchiæ in the decapod Crustacea (*fig.* 132, *g*, *n*) are in the form of long and slender quadrangular pyramids, and consist of either numerous thin plates, or minute cylinders closely arranged perpendicular to the axis of the pyramid. There are nine branchial pyramids on each side in the crabs, two being rudimental and seven forming the exterior of the pyramid in Cancroids and Maioids; but the number is more variable, and usually greater, in the Macroura, amounting to twenty-two in the lobster. In both Brachyura and Macroura slender appendages called "flabellæ" (*fig.* 132, *m*) are adapted to sweep over the surface of the branchiæ and free them from foreign particles: in the hermit-crabs and other Anomoura, this office is performed by the fifth pair of legs, which can be inserted for that purpose into the branchial chamber, the carapace being raised to admit them. By this elevation of the carapace a large quantity of water can be admitted to the branchiæ; a membrane connecting the carapace with the inner walls of the branchial chamber and extending along the anterior edge of the first abdominal ring, precludes the admission of water into the cavity occupied by the thoracic viscera.

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* Milne Edwards, Annales des Sciences Nat. tom. xi.

So far as the gills are attached to the bases of the ambulatory or natatory legs, they must be influenced by their movements; and the more active the progress of the Crustacean, the more briskly will it breathe; and, since the muscular energy directly depends upon the amount of respiration, the two functions are brought into direct relation with each other by this simple connection of their respective instruments.

The land-crabs have their branchiæ always supported by water through special modifications of the apertures of the branchial cavities, which enable them the better to retain fluid, and also by numerous folds or by a spongy structure of the lining membrane of the respiratory cavity by which the quantity of the contained fluid may be augmented. The moisture contained in the branchial chambers of the land-crabs (*Gecarcinus*) and tree-crabs (*Birgus*) is doubtless much more highly aërated than the water which bathes the branchiæ of the strictly aquatic species, and thus may explain the fact that the Crustacea which habitually live out of water are drowned by being long immersed in that fluid.

No other trace of distinct excretory organs has hitherto been detected in the present class than the simple, unbranched, long, and slender tubes which open into the intestinal canal of some of the higher Crustacea. Swammerdam* figures one such tube opening at the hinder end of the intestine in *Pagurus*. In *Maia* there are three such tubes; two inserted on each side of the pylorus, and a third a little further behind. These may be uriniferous tubes, like the corresponding parts in certain insects and spiders.

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* CCXXXIII. p. 87. t. xi. fig. 3.

Tenacity of life in the Crustacea appears not to be enjoyed in any unusual degree: but some species, as the *Artemia salina*, can exist in hot and strong brine, which would quickly destroy most other animals. This shrimp abounds in the brine-pans of the Lymington salt-works.

Like other Articulata subject to periodical ecdysis, the Crustacea have the power of reproducing lost extremities. If a leg be fractured across one of its segments, it is cast off by a violent muscular effort: if the Crustacean have not the power of thus ridding itself of the wounded member, it usually dies from the hæmorrhage; otherwise this is immediately arrested by the contraction of the lacerated part of the joint where the limb is cast off with least difficulty and pain. The pre-arranged place of easiest and safest separation is close to the basal end of the first joint, along a transverse ciliated groove. This joint is filled by a mass of nucleated cells, surrounded by a vascular band. The vessels of the band pass half an inch beyond it, and return upon themselves forming loops. The reproductive cells multiply after the loss of the limb, and form five masses, which are the rudiments of the five joints of the future limb: this, in the crab, is folded at the first joint, but is extended in the lobster: in both it is enveloped in a sac or dilated cicatrix, which the young limb, as it grows, bursts; and it then resembles in miniature the limb which it is destined to replace: its growth is slow until the period of the moult, when, if the animal be in vigorous health, the new member rapidly acquires its normal size.

Generation of the Crustacea.—With regard to some of the smaller Entomostraca, only the females have hitherto been discovered; and some naturalists have endeavoured, as in the case of the *Aphides*, to solve the phenomena of parthenogenesis in such Entomostraca by alleged gynandrism. Thus, in the genus *Apus*, the lamelliform respiratory sacs which, after death, get distended with blood, as Siebold has shown*, were described by Berthold to be the testes co-existing with ovaria, which are large and conspicuous. Again, in the genus *Cypris*, Straus-Durkheim† points out, in addition to the ovaria, a pair of sacculi at the fore-part of the stomach; but, with his usual philosophic caution, doubtfully alludes to their nature as either testes or salivary glands: they appear to me to be homologous with the cæca in the Daphnia, which most comparative anatomists have agreed in determining to be the liver; there is no other part that could be mistaken for a male organ.

In the genus *Daphnia* the males are well known; they are always smaller than the female, but have longer and larger antennæ. Müller deemed these antennæ to be themselves the male organs; they are, however, only accessories, like the claspers in the sharks, being provided with a hooked claw for holding on. Strauss points out a modification of the lateral borders of the shell, and suggests that thereby the valves of the female's shell are divaricated, and the sperm ejected into their inter-space. The ovaria are simple cœcal tubes, coiled subspirally, one on each side the hinder half of the abdomen. Several groups of ova are successively hatched within the bivalve shell, and the young are excluded during the spring and summer; these young ones propagating in a similar way, without fresh impregnation: the males do not appear until the autumn, and the ova which are then impregnated are retained in peculiar receptacles throughout the winter months, and are hatched in the following spring.

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* XXIV. p. 484.

† CCXXXIV. p. 384.

In autumn an opake layer is developed on the inner surface of the common incubating cavity, which hardens in two pieces like a small bivalve-shell, with their concave opposed inner surfaces forming a special cavity when the valves are closed; this is called the "ephippium," or saddle, being placed on the dorsal surface of the *Daphnia*, but beneath the common shell. Between the valves of the ephippium is formed a similar but smaller apparatus, attached only to the dorsal symphysis or hinge of the carapace, which also affects the form of a small bivalve shell: this is the "internal ephippium;" it includes, also, two bivalve capsules, in each of which an egg is lodged, which remains in the passive state through the winter.

If the mother have strength to undergo a moult after the formation of the winter nest, this is cast off with her outer skin, which remains with the ephippial apparatus, protecting the eggs during the winter. They are hatched by the early warmth of spring, and produce only females, which, after moulting three times, exclude a batch of ova. Now, if these be insulated, a successive production of fertile females may be observed to the sixth generation. But the germ-cells retained unchanged in the developing *Daphnia* acquire the superadded yelk and chorion of an ovum, from which the young are excluded. The males are a later production, and the winter eggs are always the products of impregnation.

In the male *Cyclops* the right antenna is peculiarly thickened and jointed a little beyond its middle, so as to permit it to be bent upon itself. With this organ the male seizes the female, and then grasps the base of her tail by the great hook of his hindmost pair of feet. After a slight resistance, she is quiet, and both gradually sink to the bottom. A cylindrical tube, filled with sperm, escapes from the orifice of the male organ, and he seizes the tube as soon as it has escaped, and glues it to the abdomen of the female above the vulva. No female has this tube prior to the coitus, and none is without it afterwards. A male fit for coitus always has this tube or spermatophore in the lower dilated half of his seminal canal, and after the coitus it is no longer there. Professor Siebold* has found the sperm-tube attached to the rounded end of the last pair of feet of the male, indicating the instrument of fixation. The females so provided are not, therefore, disdained by other males,—three, four, or even six sperm-tubes may be found attached to the same female. The sperm-tube consists of three different kinds of substance, spermatic matter, expulsatory cells, and agglutinating fluid. The action of the cells, in expanding, is to push out the spermatozoa, which, as the sac is suspended to the ventral surface of the first caudal segment, thus escape close to the vulva.

The Cyclops has a single testis, which is a pyriform sac concealed in the dorsal region, beneath or behind the heart. A long and wide sperm-duct descends to the inferior half of the body; then rises abruptly, and again descends by a sudden curve, to arrive at the sexual opening, which is simple, and at the middle of the base of the tail. In the pyriform testis are sperm-cells and also spermatozoa. In the descending part of the sperm-duct is the spermatophore, which is homotypal with the ovicapsule.

How they become occupied with their proper threefold contents has not been observed, but it does take place gradually as the spermatophore descends towards the spermatic outlet. There is no proper coitus, *i.e.*, the male does not intromit directly; but he appends or attaches the spermatophore to the female. Each spermatophore contains, besides spermatozoa, two other substances; one expulsatory, which swells in water, and expels the spermatozoa; the other coagulates in the water, and serves for the attachment of the spermatophore. The contemplation of the complex machinery requisite for this curious mode of impregnation, whilst it exemplifies the necessity of direct contact of the spermatozoa with the ova, must fill the mind with admiration at the unusual interdependent arrangement, or, humanly speaking, contrivance, which is manifested in subserviency to the propagation of an animal so minute and seemingly so insignificant.

In the genus *Cypris* the ovaria consists of two long cæcums, curved, and applied to the sides of the hinder half of body, but covered by the shell, and opening exteriorly, one by the side of the other, at the fore-part of the extremity of the abdomen, where they communicate with the canal formed by the incurved tail. The first two-thirds of the ovarium lies free in a capsule, formed by the membrane which lines the valves. The ova are minute at the blind beginning, but progressively augment in size as they approach the outlet, or the fixed vertical and terminal part of the oviduct. These little Entomostraca oviposit on some fixed foreign body, agglutinating their ova in a mass of some hundreds derived from several individuals, by a substance of a greenish filamentary structure like moss. Thus, like the ostrich, many females contribute to one nest. In four days and a half the eggs are hatched; the young come out in form like the parent; there is no metamorphosis, only the valves are of a slightly different form, and of a red colour. As the pools dry, they bury themselves in the sand or mud at the bottom; if that remains moist, the old animals survive; if it becomes dry, they perish, but their eggs retain their latent life, and are hatched on the return of rain. This explains the seemingly marvellous phenomenon sometimes observed in a shallow pool, which has been dried up in the summer, and may have long remained so, but which, in a day or two after it has been refilled with water, is found swarming with little Entomostraca.

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* LV. p. 36.; also the excellent supplementary remarks by Mr. Lubbock, CCCXXV.

In the *Branchipus stagnalis* we have another example of the rapidity of the appearance of swarms of individuals in recent pools through a similar economy of latent vitality of the ova. The *Branchipus* is characterised by the great number of its segments; the males are distinguished by their antennæ having long antler-like terminal joints or processes, which serve to retain the female; and at the termination of the sperm-ducts are two intromittent plates. There are two sperm-sacs and two testes in the form of long and straight cæca, which extend the whole length of the tail; and from the anterior dilated end the sperm-duct proceeds inwards and backwards. Both sperm-ducts soon after their origin dilate into a sperm-sac; and then proceed to a swelling at the base of the tail, where they open near a spine-bearing peduncle. The ova, when they are impregnated, are received into an external capsule. When the pools are dry, the ova have the power of retaining life for two or three years.

The generative organs attain an enormous extent in *Limulus*: they are packed closely, interblending with the ramified cæca of the liver, in both male and female, throughout the body. In the female the ovarian tubes present the dendritic or ramified disposition. We distinguish the sexes by the external character of the first pair of thoracic limbs, which are short, swollen, and hooked in the males, while in the females they are long, straight, and pointed. On the first of the abdominal respiratory limbs there is a prominent tubular appendage, on which the sperm-duct terminates; in the female there is a simple perforation at the corresponding part.

No instance of parthenogenesis has been determined in the higher sub-class of Crustacea, called *Malacostraca;* but, like other Articulata subject to periodical ecdysis, they have the power of reproducing lost extremities, as has been already explained. There is no propagation by spontaneous fission or gemmation: every species is developed from ova formed by organs peculiar to one series of individuals, and impregnated by the fertilising product of organs as peculiar to another series. But, although the male and female organs are never naturally combined in the same individual, accidental or monstrous hermaphrodites occasionally occur, in which the male organ is developed on one side, and the female organ on the other side of the same animal. This dimidiate hermaphroditism has been most commonly observed in the lobster, and is indicated by external characters. The generative orifices open on the last thoracic leg on the male side, in which the abdominal plates are smaller and more simple; whilst on the opposite side they are broader and more ciliated, and the generative aperture is situated on the middle or third ambulatory leg. This singular kind of malformation seems to depend upon the very slight connection, or want of connection, between the right and left generative organs of the same individual, whether male or female. The external apertures are always distinct on each side; and when a combination of the right and left generative organs does occur, it is by a partial union of the two testes, or of the two ovaria.

In the male *Cymothoa* both the essential and efferent portions of the male apparatus are distinct on each side: the testis is here much simplified, and consists of three elongated pyriform vesicles forming a common tube by the union of the short vasa deferentia, which arise respectively from the great end of each vesicle. In this and some other of the *Isopoda*, the disproportion between the male and female is still retained; and is almost as extreme in the parasitic *Bopyrus* as in the Lernæans.

In *Squilla*, the testes are ramified glandular lobes, from which the sperm-ducts pass off laterally to terminate each in a hollow evertible penis at the base of the last thoracic leg.

In *Astacus fluviatilis* the testes are blended together at the middle line along the posterior half of their extent, anterior to which they are separated and symmetrical: they consist of packets of minute contorted capillary secerning tubes. The vasa deferentia quit the gland at the junction of its three apparent lobes: they form many convolutions at the sides of the hinder part of the thoracic segment, where they may be distinguished by their opake white colour. They dilate into sperm-receptacles in the last portion of their course, and terminate at the small prominent orifice at the basal joints of the last pair of thoracic legs.

In the *Maia* the testis consists of an elongated and convoluted mass of extremely minute vermicular tubuli, which mass is united by a slender transverse commissural process with the testis of the opposite side. The vas deferens is formed by the gradual enlargement of the tubuli, and is disposed in a number of close convolutions, and somewhat suddenly dilates into a spiral seminal receptacle, which terminates, as in the *Astacus*, on the basilar piece of the last pair of legs. In many crabs, however, as in the *Grapsus* and *Ocypoda*, the external opening of the male organ is found on the sternal part of the last thoracic ring. The testes in the common crab (*fig.* 132, *l*) consist of a net-work of very small seminiferous tubes, occupying the lateral portions of the cephalothorax, which gradually increase in size until they form the long sperm-ducts: these (ib. *d*) form numerous convolutions on each side of the stomach, and dilate into large ejaculatory ducts before opening upon the plastron. The terminal part of the duct can be everted by a kind of erection to form a temporary organ of intromission; and the Crustacea are singularly analogous to serpents in the double number as well as the structure of this part. Certain appendages of the first and second abdominal rings in the male crabs are probably connected as exciting organs with the sexual function.

The spermatic fluid is white and sometimes opalescent: the sperm-cells present varied and remarkable forms. In the *Cyclops* they are oval corpuscles; in *Cypris* they are large, filiform, and flexuous. In the Isopods and Amphipods they are long filaments pointed at both ends, or with a slight thickening at one end: they are motionless. In the Decapoda the nucleus of the sperm-cell developes one or more filiform processes, which project from the cell itself. In fig. 134, A shows the form of the spermatozoa in the *Grapsus marmoratus*; B and C, that in *Pagurus oculatus*; and D, that in *Pisa tetraodon*.

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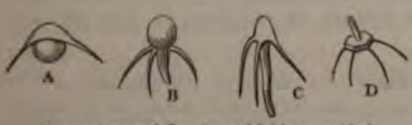

Spermatozoa of Crustacea, highly magnified.

The female organs present, like the male, a progressive complication of structure as the species ascend in the class. Most of the small Entomostraca carry the impregnated ova in appended ovisacs, like those of the Lerneæ. These sacs are not developed in the Limulus, which also differs from the smaller Entomostraca inasmuch as the ovarian mass interblends its lobes and processes with those of the liver; the oviducts form more frequent communication with each other than in the higher Crustacea, but ultimately terminate, like the vasa deferentia, by two distinct but contiguous orifices on the back part of the first abdominal lamelliform appendage.

The ovaria in the lobster are of great length on each side; the oviduct comes off from the outer part of nearly the middle of the gland, and descends to terminate at the basal joint of the third pair of ambulatory feet.

In crabs the female apparatus reaches its highest state of complication, and consists of an ovary, oviduct, and a copulatory pouch, or spermatheca, on each side. The ovaria are elongated cylindrical sacs in the *Maia* (*fig.* 135), and are divided into an anterior (*a*) and a posterior part (*b*), the short oviduct (*d*) being continued from the union of the two: the anterior parts of the ovaria are united together by a short transverse canal (*a*′); the posterior divisions are intimately united through half their extent; the spermatheca (*c*) is developed a little above the termination of each oviduct; and the spermatophora and spermatozoa in this receptacle afford favourable subjects for microscopic observation.

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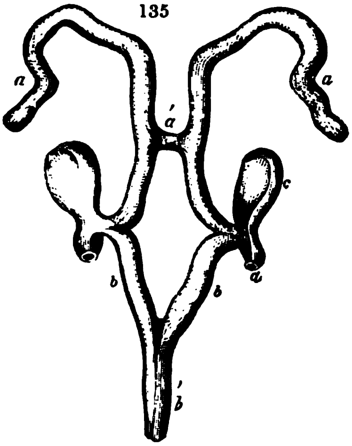

Female organs, *Maia Squinado.*

The species of a genus of Macroura (*Mysis*) are called "Opossum shrimps" from carrying their ova during the process of development in abdominal recesses, analogous to the marsupial pouch; but this superadded complexity in the reproductive economy is common, under various modifications, to all the Crustacea.

The wider our survey of living nature extends — the greater the number of facts in the history of animals with which we become acquainted — the more do the points of correspondence between the different species increase, and the clearer becomes our conception of the unity of the general plan which pervades their organisation. This is especially the case with regard to the phenomena which we recognise in tracing the development of particular animals. But, before entering on the stages of the development of the individual Crustacean, I may premise a few remarks on the phases which the class itself has passed through from the period when we first recognise its representatives among the animals that have heretofore peopled our planet.

To render my remarks on the paleontology of the Crustacea more intelligible, I may repeat that the class is naturally divisible into two great groups; but not, as Leach and Macleay believed, according to the sessile or pedunculate character of the eyes, for you find eye-stalks in Entomostracans — to use the language of Leach, "podophthalmatous" species may be found amongst the lowest Phyllopoda, *e. g.* in the genus *Branchipus*, as well as in the highest members of the class. We had to seek, therefore, for some more constant and important character for the primary division of the Crustacea, and this character we found in the constancy of the number of the segments composing the body in certain members, and the variability of the number of segments in the rest of the class. In the majority of the existing species, including the typical members of the class, the thorax includes seven segments, the abdomen seven segments, and seven are likewise indicated by the appendages in the head, twenty-one being the archetypal number of the segments in the division of the Crustacea, called "Malacostraca;" at all events, the number seven is constant with regard to the thoracic segments, and is never exceeded in the abdominal segments in this sub-class. In the lower sub-class, the number of segments varies, being often more and sometimes less than seven.

The Malacostraca, again, were divided according to the relative length of the thorax and abdomen, or according as they have "long" or "short" tails, as the latter part is commonly called; in accordance with which, the technical names of these subdivisions, or orders, have been devised. The lobster is the type of the *Macroura*, or long-tailed order, and the crab of the *Brachyura*, or short-tailed Crustaceans. But Nature never moves *per saltum*, and there is a little group which has an intermediate proportion of the abdomen, and it has been called "*Anomoura*."

All the three orders are represented in the tertiary formations and in their pliocene, miocene, and eocene divisions; but no species of crab, or brachyurous Crustacean, has hitherto been met with in strata more ancient than the eocene. In the chalk formation, the highest form of Crustacean would be classed with the *Anomoura;* but the *Macroura* are the prevalent forms. Lobsters, crawfish, shrimps, and other *Macroura,* but all of species now extinct, are met with fossilised in the secondary strata, from the chalk to the coal formation; but below the chalk, there are no higher forms of Crustacean than the *Macroura.* When we come to the coal-measures, the Malacostraca disappear; but we then find the gigantic Entomostracan called the King-Crab (*Limulus*); thence down to the lowest strata in which any trace of animal life has been found, the Crustaceous class is exclusively represented by Entomostracous species, and more particularly by a peculiar form of Entomostraca, which became extinct before the coal-measures were deposited. Almost endless, however, are the varieties under which this form was manifested in the Palæozoic periods: the term "trilobite" is given to the fundamental type or form, on account of the segments of the body being divided into three lobes.

Our countryman Lhwyd, or Lloyd, first discovered this fossil in 1699, and he gave it the name of *Trinucleus.* At that time zoological science was not sufficiently advanced to afford a definite binomial sign for the extinct animal; and Lloyd's name rather indicated the petrifaction as such, than a species of the animal kingdom. The idea of the place of the Trilobite in that kingdom began first to be mooted about the time of Linnæus, by whom it was consigned to the class of insects, with the name of *Entomolithus paradoxus.* Knorr next studied it, and gave it the name of "Trilobite," believing it to be allied to the molluscous Chitons, which opinion prevailed to the time of the Entomologist Latreille, and died with him. The better preserved fossils, in fact, gave evidence of distinct organs of vision, large compound eyes, with a cornea divided into numerous segments, thus proving that the Mollusca could not be the primary division of animals to which the Trilobites belonged; and since that time all naturalists have agreed in referring these fossils to the Crustacea.

With regard to their nearer affinities, all who had studied the Trilobites up to 1843, were of opinion that they were allied to the higher, or Malacostracous, division of the Crustacea; and Mr. Macleay, in his valuable appendix to "Murchison on the Silurian Strata," places the Trilobites in a distinct order between the Isopoda and Aspidophora. He based his views on the trilobed character of the segments in *Serolis* and *Bopyrus,* and showed that the eyes were large, sessile, and compound in *Cymothoa,* as in Trilobites. The *Cymothoa* and other Isopods roll themselves up into balls, as we find many of the Trilobites to have done before they perished. But we find these characteristics also in *Limulus:* the segments of the hinder division of its body are divided into three elevations, or lobes; the large, sessile, compound eyes of *Limulus* are more like those of the Trilobite than the eyes of any Isopods are; and the larval *Limuli* roll themselves into a ball. Moreover, the excess in the number of the segments of the thorax or abdomen, over and above the number seven which governs them in the Malacostraca, proves the particulars of resemblance to the sessile-eyed members of that sub-class, which Mr. Macleay indicates, to be no characters of immediate affinity to the *Cymothoidæ* or to the *Epicarides*, although some of these, like *Sphæroma*, may present a large, convex, semicircular anal segment, such as we see in the Trilobitic genus *Bumastus* of the Silurian strata.

In a lecture on the Crustacea, delivered at the Royal College of Surgeons, April 27, 1843, and published in the following month, I introduced the Trilobites with the following remark:—"The distinction between the Entomostraca and Malacostraca, in the numerical character of the segments of the body, is of the first importance in determining the affinities of those ancient extinct Crustacea, called 'Trilobites.'"* And I pointed out how *Bopyrus* and *Cymothoa* differed by their normal number of thoracic and abdominal segments, viz., 7—7. M. Burmeister, in the same year (1843), with equally original views of the importance of this numerical character, also availed himself of it, in determining the position of these extinct animals in the Systema Naturæ, and showed how it invalidated the marks of resemblance which had been noticed between certain Isopods and Trilobites. But he errs, I believe, in thinking *Limulus* to be still more widely removed from the Trilobites than the Isopods are, not apparently knowing the King-crab in its larval state. Professor Emmerich, in a memoir in Bronn's Neuer Jahrbuch, 1845, regards the Trilobites as a peculiar order, connecting the Malacostraca with the Entomostraca, but more nearly related to the latter. He thinks them allied to the Malacostraca by their crust-like shell, and by their not possessing simple eyes together with compound ones; but this combination is rare even in the Entomostraca. He deems the *Xiphosura* and the *Phyllopoda* to be the two orders of Entomostraca to which the Trilobites are united by the nearest characters of affinity. They correspond with both as regards the form and size of the clypeoid head or cephalo-thorax. The soft texture of the under side of the body of the Trilobites, and the circumstance that no one has yet succeeded in detecting unequivocal vestiges of legs, are in favour of the supposition that they must have corresponded, in the perishable structure of their feet, with the *Apus* and *Branchipus.*

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* LXXXIV. p. 165.

But, to what end, it may be asked, tends all this discussion concerning the affinities of animals that have long since ceased to exist? How are we concerned with it, in considerations relative to the generation and development of the actual Crustacea? To this I have to answer, that it is only by a knowledge of the transitional larval forms of these, that we come rightly to comprehend the nature and affinities of the extinct Trilobites; and that our knowledge of the most interesting relations of actual larvæ requires a previous knowledge of the forms of their class that have heretofore existed in this planet. In no mature stage of any existing Crustacean do we find the trilobites so closely resembled, as they are by the larval stages of the Limulus, and of some of the smaller Entomostraca. The metamorphoses of these are such that different stages are figured as distinct species in the well-known work "On Entomostraca," by O. F. Müller.* In the larval *Cyclops*, which is his genus *Nauplius*, the body is rounded and without the tail; it has only two pairs of limbs: the eyes are distinct; but, in the course of the first and second moult they approximate, and finally unite together. The body of the larval *Branchipus* consists at first of two oval divisions, like the spiders: that which represents the thorax and abdomen united has no legs; but two pairs of natatory setigerous legs, and two antennæ, are developed from the head, which has a single median eye. The form of the head is also different from that of the parent. After the first moult the head has three eyes, a pair being added to the first median one; but all are sessile. The abdomen elongates, and divides into rings, and is now provided with rudimentary tubular feet. At the secondary moult, the first pair of foliaceous feet appear, and are succeeded by seven pairs of rudimentary ones. In succeeding moults the lateral eyes become pedunculated, and the median eye disappears; the abdomen grows longer, and its limbs are perfected. The *Apus* quits the egg with fewer segments than it afterwards acquires. The larval *Sao* has but three thoracic segments, but the number of these increases with each successive moult, until the adult form is acquired; the new segments being developed between the thorax and abdomen. Similar metamorphoses have been evinced by fossil specimens of the tribolitic genus *Ogygia*, in which the additional segments were developed at the hinder part of the abdomen.

* CCXXXV.

One cannot witness the earlier stages of *Branchipus* and *Apus* without being struck by their resemblance to certain forms of Trilobites. And so likewise with the larva of *Limulus*. The argument against the affinity of this genus to the Trilobite which had most weight with Burmeister, was the peculiar bayonet-shaped weapon proceeding from the post-abdominal division of the body in the fully-developed King-crab. Now, when it quits the ovum, this weapon is not developed; the cephalo-thorax is relatively smaller; the abdomen longer, and more trilobed, and altogether the larva is much more like the Trilobite than the later stages. The cephalo-thoracic shield is enormous in the larval *Sao*, but becomes reduced to comparatively small dimensions in the adult animal. Some of the forms of the smaller Trilobites, which figure as distinct genera, e. g. *Battus* and *Agnostus*, may also be larval forms of other genera; for, like the existing Entomostraca, the Trilobites underwent their metamorphoses, which, as in the case of *Ogygia*, were, also, of a similar nature. Therefore, by these facts in the development of the lower Crustacea — few indeed, I admit, when compared with the great number of known Entomostraca that now exist — a clearer light is thrown on the real nature of those ancient Trilobites than could have been expected in regard to extinct creatures, the affinities of which were so long and so hardly considered problematical.

The ova, after exclusion from the oviducts, are retained and pro-
[illegible] and other sessile-eyed Malacostraca by means
[illegible] appendages of the thoracic extremities, which ap-
[illegible] expanded, and overlap each other, so as to
[illegible] a temporary receptacle, in which the incu-
[illegible] completed. In the Podophthalma, the lamelli-
[illegible] appendages of the abdominal segments include similar
[illegible] recesses for the ova. The female lobster
[illegible] are distinguished from the male by the greater
[illegible] these appendages; and in the Brachyura the shorter
[illegible] is so much more expanded in the females as to cover
[illegible] whole sternum, and render the sex distinguishable at a
[illegible]

[illegible] to the higher group of Crustacea, up to a late period
[illegible] believed that they differed from insects, as well as
[illegible] in undergoing no metamorphosis; but they offer
[illegible] this respect in different species. The phenomena of
[illegible] common to all are the following:—The primary germ-
[illegible] impregnation of the ovum, propagates its progeny not at
[illegible] the whole germ-yolk, but only of a small portion of
[illegible] process of yolk-fission is a partial, not a total one.

All Crustacea show the same direction of development,—*i. e.*, they obey the law of the Articulate type by the commencement of the embryo at its ventral surface,—it is literally built up from below; and consequently the umbilicus, or the last cicatrix closing in the yolk-sac, is on the back; the body is completed by the finishing of the segments or rings at the dorsal surface of the body. In regard to the Malacostraca, there are many modifications of the secondary or subsequent phenomena of development. As long ago as 1778, a Dutch naturalist, Slabber*, described and figured a minute swimming Crustacean of the genus called *Zoea* by modern naturalists; it was provided with a pair of large and distinct eyes; its carapace was armed with a long frontal and a dorsal spine; and its abdomen was terminated by a forked tail. He preserved this little animal alive in sea water, which was daily renewed, and on the fourth day he found that the animal had moulted and changed its form; the feet, eyes, and antennæ were more developed, the frontal spine had become comparatively small, the dorsal one had disappeared, and the tail had changed from the bifurcate to the spatulate shape, and was fringed by a row of short spines. Many years elapsed ere this observation was repeated, and it seems to have been forgotten, when Dr. Leach, the most accomplished Crustaceologist of his day, founded the principal character of the class Crustacea on the absence of metamorphosis.

During the spring of 1822, Mr. V. Thompson†, to whom we are indebted for the discovery of the metamorphoses of the Cirripeds, captured an abundance of the singular Zoeas in the harhour of Cove; the largest of them was daily supplied with fresh sea-water from May 14th until the 15th of June, when it died in the act of changing its skin. The disengaged members, invested with the new integuments, were changed both in number and form, and corresponded with those of the decapod Crustracea, the anterior pair being furnished with large pincers. Here, therefore, was a strong indication that, under the form of a Zoea, was masked that of some one or other of the higher Crustacea; and, probably, one of the common species of the Irish coast. To the development of these, therefore, Dr. Thompson next turned his attention, and he succeeded in hatching the ova of the common crab during the month of June, and found that the young were excluded under the form of the *Zoea Taurus*, with the addition of lateral spines to the thorax; whereupon he concluded that the decapod Crustacea indisputably underwent a metamorphosis.

These observations were, however, called in question, after the

* CCXXXVI.

† CCXXV. No. 1. 1828.

appearance of the elaborate monograph by Rathké, on the development of a freshwater species.

In the year 1829, Dr. Rathké published his "Researches on the River Craw-fish (*Astacus fluviatilis*).[*] In this species the ovum first appears in the shape of a minute transparent vesicle, which afterwards becomes surrounded by a second, forming the membrana vitelli : the nature of the processes effecting this stage appears not to have been observed. The yolk increases in quantity, and is rendered opaque by the presence of numerous granules, or nucleated cells, which are at first angular, and change from the lenticular to the spherical figure ; then the internal minute transparent germinal vesicle quits the centre, and comes into contact with one part of the parietes of the ovum. The colour of the yolk successively changes to yellow, orange, and brown ; the spermatozoa, enveloped in their spermatophore, when they are received into the oviduct, escape therefrom, and ascend the duct to the ovarium, and after coming into contact with the ovum, the clear vesicle disappears, and the production of the embryo commences. Rathké failed to ascertain what became of the vesicle. The formation of the ovum in the ovary continues half a year. In the month of November, the vesicle was visible ; in the ensuing March it had disappeared.

The ovum escapes into the oviduct by bursting the inner lining of the ovary. It is surrounded by a layer of albuminous matter, and is enclosed within a coriaceous chorion, and an irregularly doposited nidamental tunic, by which the ovum, after exclusion, becomes attached to the ciliated plates beneath the tail of the mother.

The first appearance of development is as a whitish cloud of indeterminate form, spreading over the vitellus, and assuming, as it extends, a reticulated appearance. It seems as if the germ-cells had propagated themselves over the superficies of the yolk-mass. A discoid portion of the opake layer is defined from the rest, and increases in thickness at its middle part: its longest diameter is about half the radius of the egg. A depression appears in the centre of this, which passes more and more deeply into the vitellus, and the embryonic spot expands at its margins The patch next grows heart-shaped, and the antennæ, the labrum, mandibles, and abdomen become simultaneously recognizable (*fig.* 136). The first appearance is a minute median prominence, which becomes the labrum *e;* that part of the mouth which we find most constantly in the Crustacea. Then the

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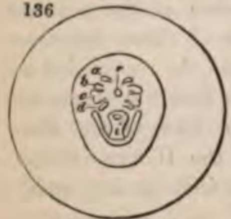

Astacus fluviatilis.

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[*] CCXXXVII.

other parts appear in pairs; the antennæ (*b*, *c*), at first short and simple processes, increase in length, and their extremities become notched; the mandibles (*d*) also lengthen and enlarge, particularly in their basal portion; the labrum recedes from between the anterior antennæ, and takes its station between the posterior: the eyes (*a*) now make their appearance. All these parts are, at first, slight elevations above the surface of the germ. A cavity is formed behind the labrum, which communicates with the commencement of the œsophagus; the tail or abdomen (*i*) elongates, and the depression in its surface is converted into the anus; the rest of the alimentary canal is a simple wide sac, which, by the extension of the mucous layer of the germinal membrane, now includes the vitelline mass.

The three anterior pairs of maxillæ begin to show themselves at a little distance behind the mandibles, and afterwards the fourth and fifth pairs; the last (*fig.* 137, *g* 5) increasing in size more rapidly than the rest. Thus, including the eyes (*a*) and the two antennæ (*b*, *c*), nine pairs of appendages may now be recognized, of which the two last belong to the thorax: the five posterior pairs of thoracic members, which are not, like the first two, developed into jaws, are produced in regular succession from before backwards from that portion of the body which is turned upwards, or the epimeral elements of the rudimental segments. Each pair of legs at its first appearance is exactly similar to the hindermost maxillæ; these, therefore, are retained in the service of manducation by an arrest of development. The ambulatory legs increase inversely with respect to the maxillæ, the anterior (*fig.* 137, *h* 1) soon acquiring four times the size of the posterior (*h* 5). The rudiments of the future branchiæ next appear as small processes from the base of each leg. The seven segments of the third division of the body may now be distinguished by six transverse furrows, and by the rudiments of foliaceous appendages. Part of the cephalic segment (*m*) above the antennæ is the basis of the great shield which afterwards covers the whole cephalothorax; it grows upwards and backwards until it meets its fellow along the median line of the dorsal aspect, and so completes the carapace.

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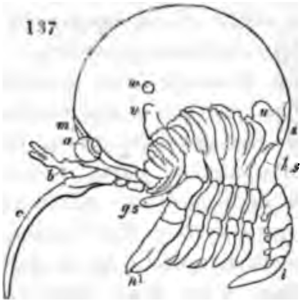

Astacus fluviatilis.

The heart (*s*) appears at first in the shape of a small compressed vesicle, or "punctum saliens," situated near the junction of the anterior and posterior divisions of the body: blood-vessels seem to be prolonged from it, and its pulsation speedily becomes distinguishable. The nervous system consists at first of two parallel lines, on each of which are eleven minute white spots: from the anterior of these a short and broad process passes forwards on either side of the œsophagus. The above described stages of development are in progress from the beginning of April to the middle of May. The whole of the organs continue to approach more nearly to their mature form. The brain, liver (*v*), and salivary glands next make their appearance. The outer integument of the body is developed from the ventral to the dorsal aspect, and the yolk-laden intestine is finally, with the heart, walled in by the confluence of the lateral lobes of the integument along the middle line of the back.

The integument is very soft when the animal quits the shell: the young craw-fish subsists, at first, on the remaining portion of the yolk, during which time its coat becomes sufficiently hardened to admit of its moving about in quest of food with more safety. The different appendages increase in length, and more especially the branchiæ, the growth of which is now remarkably rapid. The changes of the interior parts of the animal, with the exception of the development of the sexual organs, consist in a gradual adaptation of parts already formed to their proper functions. The relative positions of embryo and vitellus are the same in the craw-fish as in the *Daphnia pulex* and *Branchipus stagnalis*. The maxillæ present at an early period a considerable resemblance to those of the *Apus;* the legs, at the period when they are devoid of branchial appendages, typify the persistent condition of the Branchiopoda; after the branchiæ are developed, and before they are enclosed in the branchial chamber, the characteristic persistent condition of the respiratory system of the Edriophthalma and Stomapoda is sketched out.

M. M. Audouin and Milne Edwards have shown that the successive changes of development of the nervous system of the craw-fish correspond in like manner with distinct types of formation observed by them in its permanent condition in lower species of the class; thus the two series of ganglions, which first indicate the subœsophageal central part of the nervous system in the embryo craw-fish, are analogous to the permanent state of the nervous system in the mature *Talitrus*. At a more advanced period, the two series of ganglions in the fœtal craw-fish approach the median line and become united together as in the abdominal ganglionic chain in the adult *Cymothoa*. We have seen, that in the brachyurous Crustacea a further concentration takes place by the longitudinal blending together of the whole series of the subœsophageal ganglia, which clearly indicates that the brachyurous Crustacea are more highly developed than the macrourous species; contrary, however, to the opinion of Rathké. The eyes are at first sessile in all Crustacea.

It is certain that the moult of the young craw-fish is not at any period accompanied by a marked change in the form of the body, or in the structure and functions of the locomotive members; this Crustacean, in short, undergoes no sudden metamorphosis. The progress of development is not interrupted by arrested phases.

A series of less complete observations on the ova of a species of land-crab (*Gecarcinus*), more recently published by Westwood*, lead to the same inference in respect of that species; although the macrourous proportions of the abdomen, and the exposed position of the gills at the base of the thoracic legs, obviously unfitted the larva for land life, and demonstrated the necessity for the parent's migration to the sea. Nevertheless, this accomplished entomologist coincides with Rathké in the general conclusion, that the Crustacea undergo no metamorphosis, and that the contrary evidence adduced by Slabber and Mr. Thompson must depend on some erroneous observation.

The opposite conclusions of both parties from the phenomena afforded them by the solitary species examined, may be compared with analogous premature generalizations which might have been drawn, in reference to the class of Insects, by the observer of the development of a cockroach on the one hand, and by the observer of the metamorphoses of a butterfly on the other. As reasonably might the one, after detailing the progressive development of the orthopterous insect, broach the inference that insects underwent no other metamorphosis than the gradual acquisition of wings; and, with equal reason, might the other observer of the wonderful changes of the lepidopterous insect affirm them to be characteristic of all insects. It needs only that each theorist should question the reality of the other's observation to make the parallel complete. The failure of both to arrive by so short and easy a route at the entire truth inculcates the necessity of acquiring a sufficient foundation, by careful and extensive induction of facts, before proceeding to erect the superstructure of general theory.

With regard to the metamorphosis of the common crab, valuable testimony in confirmation of Mr. Thompson's discovery has been contributed by Capt. Du Cane, R. N.† This gentleman obtained crabs with ova under their tails in the month of December, from which the larvæ were produced in the months of March and April. The form under which they first appear is represented in *fig.* 138.:

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* CCXXXVII. p. 311.

† CCXXXVIII. p. 438.

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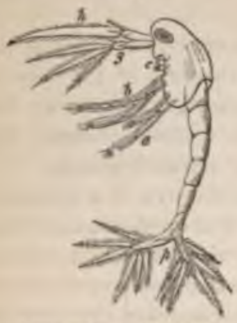

Larva of Crab. First stage.

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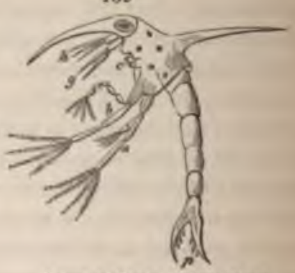

Larva of Crab. Second stage.

they are then about half a line in length. Soon after exclusion this larva casts off its envelope and assumes the appearance represented in *fig.* 139., which closely corresponds with that zoëæiform Crustacean whose further changes were witnessed by Thompson, and which he had assured himself was an early or larval state of a common crab. The last form which immediately precedes the assumption of the mature characters corresponds, according to Thompson, with that of the genus *Megalopa*.

The additional evidence adduced, in 1839, by Capt. Du Cane in proof of the actual metamorphosis of the Crustacean in question, was most acceptable. He affirms a corresponding metamorphosis to occur in the ditch-prawn (*Palemon variabilis*) and common shrimp (*Crangon vulgaris*). Dr. Thompson has witnessed similar metamorphoses in the genera *Palinurus, Squilla, Pagurus, Porcellana, Galatea*, and the marine species of *Astacus*, as well as in *Palemon* and *Crangon*.

Mr. Couch, a medical gentleman residing on the coast of Cornwall, contributed further conformation in a paper to the Cornish Natural History Society in 1843*, in which he described, with much care and detail, the metamorphoses of the common crab. The nervous system first appears on the ventral aspect of the embryo; at this period it agrees in its arrangement with that which is persistent in the edriophthalma, and the eyes of the larval crab are likewise now sessile. A second metamorphosis takes place, when the eyes become supported on long and thick peduncles. None of the phenomena are more remarkable than that of the nervous system, where ten pairs of ganglia are consolidated into one great central ganglion in the crab.

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* CCXXXIX. p. 28.

With respect to the *Maia*, or spider-crab, also, there is a very complete metamorphosis. According to Couch, in both kinds of crab the larva quits the ovum in a form more strictly aquatic than the adult; and this gives us an insight into the curious law of the periodical migrations of the land-crabs (*Gecarcinus*) of the West Indies to the sea.

Brown, in his "History of Jamaica," gives a graphic account of these migrations. About the month of February or March they may be seen in crowds on their way to the sea-side, impelled thereto in order to deposit their ova in the sea. These ova have been excluded from the oviduct, and are attached, by the nidamental gluten, to the ciliated sub-caudal appendages; and Brown's idea was, that it required the sea to wash them off. But now, as we know that the larval land-crabs are natatory and more especially fitted for sea life, we see the necessity for the migration of the parent-crab to that element for oviposition.

Finally, the metamorphoses of another species of shrimp (*Caridina Desmarestii*) have been described with all the requisite care and detail by M. Joly, in the "Annales des Sciences Naturelles" for January, 1843. The development of the ovum, up to the period of exclusion and attachment to the maternal ciliated plates, closely corresponds with that described by Rathké in the *Astacus fluviatilis*. The first stages in the formation of the rudimental extremities, — the first steps in the definition of the alimentary canal and circulating system, were likewise the same; the heart was observed to beat thirty-five times in a minute in the embryo *Caridina*. But the formation of the abdomen is anterior to that of the antennæ, the labrum, and the maxillæ; and the ambulatory thoracic legs precede the masticatory pairs in their formation. The young *Caridina*, moreover, is born with only three pairs of jaws, and the representatives of the ambulatory feet are bifid, like those of the *Mysis*, and are at first likewise only in three pairs. The abdominal segments are without any vestige of lamelliform limbs.

The bifid feet of the larva are metamorphosed into auxiliary jaws, and the later bifid thoracic limbs are metamorphosed into the ordinary ambulatory legs. With respect to the branchiæ, they are not at all developed when the young Caridina quits the ovum. The first moult takes place three days after exclusion from the egg; the subsequent ecdyses are numerous, and take place at long intervals. It is unquestionable that the Caridina, unlike the Craw-fish, is excluded neither under the form, nor with all the parts which it possesses in its mature shape. It wants, for example, the branchiæ, a certain number of maxillæ, the ambulatory thoracic, and the lamelliform abdominal feet; it possesses neither the squamous tail nor the complex stomach of the mature creature.

The cumulative evidence of the metamorphoses of *Crustacea* can no longer be rejected; but their modifications in different genera, and the number of the exceptions to the law, like that presented by the *Astacus fluviatilis*, are yet to be determined. Here, therefore, is an ample field open to the researches of the original observer; a field which must be diligently and extensively cultivated before it can yield the fruits of true generalisations as to the extent, the nature, and varieties of the metamorphoses in the class of articulate animals which support their bodies on jointed limbs and breathe by gills.

Sufficient has been observed to show, that if certain stages of the development of a higher Crustacean were arrested, and growth alone proceeded with, an animal would result having the characters of the Crustacea of an inferior order. The Crab is "anomourous" before it becomes brachyurous; at an earlier period it is "macrourous," and it is "edriophthalmous" before it becomes "podophthalmous;" all which stages typify the successive forms of the Crustacea, as they were introduced into this planet. The entomostracous characters were never overpassed by the Crustacea anterior to the coal measures, and the type of the Macroura did not begin to be departed from until the period of the deposition of the chalk. All the decapod Crustacea are, at first, macrourous, or manifest the Oolitic type; and all Brachyura pass through the anomourous or cretaceous type before the proper brachyurous or tertiary character is finally acquired. But these resemblances are general, and by no means exact in specific details. No extinct species could be reproduced by arresting the development of any known existing species of Crustacea; and every species of every period was created most perfect in relation to the circumstances and sphere in which it was destined to exist.

Class CRUSTACEA.

Body articulated, with articulated limbs: *head* with antennæ: branchial respiratory organs. Sexes distinct. Metamorphosis in most; in none resulting in fixed individuals.

Subclass ENTOMOSTRACA.

Body with more or fewer segments than fourteen; integument chitinous. Eyes sessile.

Order Trilobites.

Abdominal segments trilobed: limbs rudimentary, lamelliform, probably branchial: sessile compound eyes in most.

Genera *Asaphus*, *Calymene*, *Bumastus*, *Trinucleus*, *Ogygia*, &c. (all extinct).

Order XIPHOSURA.

Abdominal segments trilobed: limbs forcipated and lamelliform: branchiæ lamelliform and abdominal: a sword-shaped caudal appendage.

Genus *Limulus*.

Order PHYLLOPODA.

Body divided into numerous segments, with lamelliform branchial limbs. Eyes sometimes confluent, sometimes distinct and subpedunculate.

Genera *Branchipus*, *Apus*, *Limnadia*, *Artemia*.

Order CLADOCERA.

Body articulated, defended by a bivalve carapace, and with membranous lamelliform branchial limbs. Eyes, in most, confluent.

Genera *Daphnia*, *Evadne*.

Order OSTRAPODA.

Body obscurely articulated, defended by a bivalve carapace, with natatory limbs. Eyes confluent.

Genera *Cypris*, *Lynceus*.

Order COPEPODA.

Body distinctly articulated, with many pairs of natatory limbs; females with external pendent ovisacs.

Genera *Cyclops*, *Cyclopsina*, *Anomalocera*, *Calanus*.

Sub-class MALACOSTRACA.

Body divided into thorax and abdomen, with seven segments in each.

Division EDRIOPHTHALMA (with sessile eyes: no carapace).

Order LÆMODIPODA.

Abdomen rudimentary; palp of thoracic limbs vesicular and branchial.

Genera *Cyamus*, *Caprella*, *Leptomera*, *Aegina*.

Order ISOPODA.

Abdomen normal, with branchial limbs: thoracic limbs subequal, uncinated, with basal marsupial plates in the female.

Genera *Cymothoa*, *Sphæroma*, *Idotea*, *Asellus*, *Oniscus*, *Bopyrus*.

Order Amphipoda.

Abdomen terminated by saltatory or natatory appendages: thoracic limbs unequal, with basal vesicular branchial appendages.

Genera *Amphithoë, Talitrus, Gammarus, Hyperia, Phronima, Vibilia.*

Division PODOPHTHALMA (with eye-stalks, and a cephalothoracic carapace).

Order Stomapoda.

Branchiæ exposed, usually tufted, attached to the abdominal and (in some) to a few of the thoracic limbs: rarely abortive.

Genera *Phyllosoma, Amphion, Mysis, Lucifer, Cynthia, Alinia, Squilla.*

Order Decapoda.

Branchiæ in cavities at the sides of the thorax: first two thoracic limbs serving as jaws: the other five chelate, uncinate, with the last pair sometimes lamellate. Crust commonly calcified.

Tribe *Macroura.* (Abdomen long, with lamelliform limbs, and terminated by a natatory appendage. Antennæ long.)

Genera *Penæus, Alpheus, Caridina, Hippolite, Palæmon, Gebia, Callianassa, Crangon, Nephrops, Astacus, Homarus, Palinurus, Scyllarus, Galathea.*

Tribe *Anomoura.* (Abdomen moderately long, not a natatory organ. Antennæ long.)

Genera *Pagurus, Birgus, Porcellana, Remipes, Ranina, Homola, Lithodes, Dromia, Dorippe.*

Tribe *Brachyura.* (Abdomen short, bent beneath the thorax. Antennæ short.)

Genera A. *Matuta, Calappa, Leucosia;* B. *Pinnotheres, Grapsus, Gelasimus, Ocypoda, Gecarcinus, Thelphusa;* C. *Portunus, Cancer;* D. *Maia, Inachus.*

LECTURE XVI.

INSECTA.

Although spontaneous locomotion is the peculiar attribute of the Animal Kingdom, we have seen that the lowest members, the Zoophytes as they were termed, were, for the most part, fixed and rooted like plants: we have seen that the first manifestations of locomotion were of the feeblest and simplest character, a rowing of the body through an element of equal density with itself, or a trailing of the body along the ground, which supported it at every point. As we advanced to the survey of the Articulate series of animals, we saw the integument progressively hardened; divided into segments which were united by flexible joints; at length supported upon moveable jointed limbs, consisting of hollow columns of integument compacted into a dense exterior crust, capable of serving the office of levers and fulcra, whereby the animal could raise its belly from the dust, and swiftly traverse the surface of the ground.

We now come to a class of *Articulata* in which the highest problem of animal mechanics is solved, and the entire body and its appendages can be lifted from the ground and be propelled through the air. The species which enjoy this swiftest mode of traversing space breathe the air directly: but their organs of respiration are peculiarly modified in relation to their powers of locomotion; they consist of innumerable tracheæ commencing from lateral pores called stigmata, or by anal tubes, which are ramified through and over every tissue and organ of the body. The nervous system is homogangliate; the organs of sense include two jointed antennæ and two compound eyes; the skeleton is principally external, and cut deeply into segments, whence the name of the class *Insecta.*

Not every Insect, however, has the power of flight, nor any Insect save in its last and most perfect state; many undergo most remarkable transformations before they acquire their wings, and although some Insects, which ultimately are so endowed, undergo a less amount of change, yet the metamorphoses are always least remarkable in the apterous species.

Of these lowest members of the class of Insects, many have more than three pairs of legs, have sometimes indeed eighty pairs and upwards in their mature state: metamorphic development exhausts itself, as in the Anellides, in the successive acquisition of new segments * and legs in addition to those which previously or originally existed; these Insects are therefore termed *Myriapoda.*

True or *Hexapod* Insects have thirteen rings; one for the head, three for the thorax, and nine for the abdomen. Certain flying Insects in their early or larval state present several pairs of rudimental feet, in addition to those attached to the first three segments succeeding the head; but no true Insect in its mature state has more than the three pairs of articulated limbs just indicated.

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* Always, as De Geer, Savi, and Newport have shown, developed between the penultimate and anal segments.

The common or typical number of articulated legs, therefore, in this class, is *six;* disposed in three pairs developed exclusively from the thorax. In the Crustacea we saw that the number was greater, and that the limbs were developed from the abdominal as well as from the thoracic segments of the trunk. Such is the case also with the Myriapodous Insects; but these breathe the air directly by means of tracheæ, not by gills, and they have only one pair of antennæ: they likewise manifest, as we shall find, the typical Hexapod character in their larval state, — a period during which, as in the Cirripeds, Epizoa, and Acalephæ, the Myriapod shows more of its true nature and is more in accordance with the common type than during its final and oviparous stage.

Taking, however, a survey of the tracheal air-breathing Articulata under their mature condition, they present more important characters in common than any which indicate an affinity to the gill-bearing classes; and we find them offering the same ground for a primary division as the Crustacea did, viz., in the number of the segments of the body.

This number is constant and definite in the higher and typical members of the group, in which it is neither more nor less than *thirteen:* in the rest it exceeds thirteen, and is variable.

There is no distinction between thorax and abdomen in the indefinitely-jointed division; and all the segments, save the first and last, support jointed limbs. The Myriapoda I regard as a group equivalent in the tracheal Articulata to the Entomostraca in the branchial Articulata; and, like them, they are the lowest organised, and the least numerous and varied of the two divisions of their primary group. The Myriapodous sub-class is divided, according to modifications of the mouth, into *Chilognatha* and *Chilopoda,* answering to the genera *Iulus* and *Scolopendra* of Linnæus, who first detected these natural divisions.

The Hexapod Insects may be classified, —

1st. According to the phenomena of their development;

2nd. According to the structure of their mouth; or

3rd. According to the nature of their wings.

Agreeably with the first character they would be divided into, —

Ametabola, or those that undergo no metamorphosis;

Hemimetabola, or those that undergo a partial metamorphosis; and

Metabola, or those that undergo a complete metamorphosis.

According to the modifications of the trophi, instrumenta cibaria, or oral organs, the Hexapod Insects are divisible, like the Myriapods, into two groups, viz., the *Haustellata* or suckers, and the *Mandibulata,* or chewers and biters.

But this binary division is insufficient for the general propositions which the comparative anatomist has to enunciate; and I take, therefore, the third kind of characters, the value of which was first fully discerned by Linnæus, viz., that founded upon the organs of flight. Those Hexapod Insects which are devoid of wings are called *Aptera;* those with two wings only are the *Diptera.* All the rest have four wings. The *Lepidoptera* have four scaly wings; the *Hymenoptera* have four veined wings, crossing each other when at rest; the *Hemiptera* have one pair of wings partially thickened, and called hemelytra; the *Orthoptera* have one pair of wings wholly thickened, the other folded lengthwise; the *Coleoptera* have one pair wholly and much thickened, called elytra, and the other pair folded crosswise; the *Neuroptera* have four reticulated wings; the *Strepsiptera* have one pair of wings rudimental and curled up. In the *Aphaniptera* both pairs are rudimental and functionless as wings. Of these orders the first five are "haustellate;" the next four are "mandibulate." The Aptera are ametabolian; the Hemiptera and Orthoptera are hemimetabolian; the remaining orders are "metabolian." These characters, therefore, briefly and succinctly express the highest generalisations, as yet reached, relative to the Hexapod Insecta.

Although, typically, the Hexapods have thirteen segments, in the last stage of the metabolian orders, one, two, or three segments may become blended together; and although we reckon the head as a single segment, the number of jointed appendages which it supports, under the name of antennæ, mandibulæ, maxillæ, palpi, &c., indicates that here, as in the Crustacea, it consists essentially of several coalesced segments.

With regard to the orders of the Myriapoda, the *Chilognatha* have two biarticulate mandibles, without palpi, armed with imbricated teeth planted in a cavity at the upper extremity of the mandible; they have also a kind of lip situated immediately beneath, and covering the mandibles, notched into four divisions, and answering to the two pairs of maxillæ of the Crustacea; whence the name from the Greek, signifying, "feeding by jaws." The Iulus, or Gally-worm (*fig.* 140), is a type of this order. The *Chilopoda* have the mouth composed of two mandibles, with a small palp; a quadrifid lip, also the homologue of the crustaceous maxillæ confluent; two labial palpi, hooked at the tip; and a second pair of jaws, or foot jaws, — the obvious homotypes of feet, — terminated by a strong hook, moveable, and pierced beneath the extremity by a poison-duct. The Centipede (*Scolopendra*) is the type of this order of Myriapods, which "feed by feet."

Every Insect has a distinct head (*fig.* 140, 141, *a*), provided with one pair of antennæ (*c*), and every true or Hexapod Insect has its trunk divided into two regions, called thorax (*d, f, i,*) and abdomen (*ab*).

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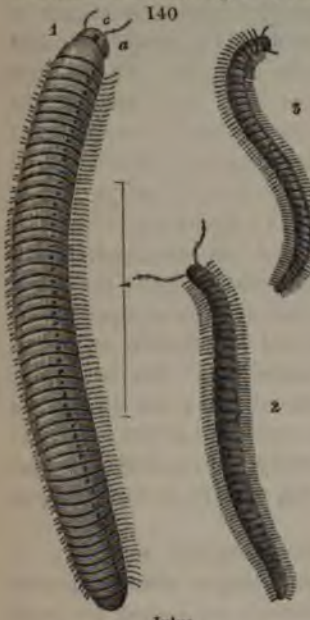
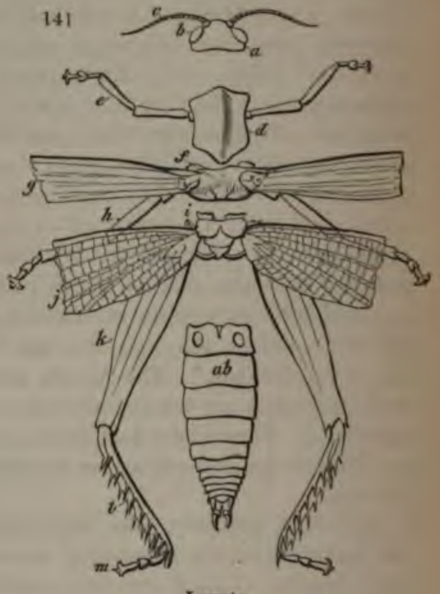


Iulus.

141



Locusta.

The thorax is interposed between the head and the abdomen, and so far is analogous to that part in human anatomy; but it has neither the same relation to the contained viscera nor to the locomotive extremities which characterises the thorax in the vertebrate animals. To the Insect's thorax are attached all the locomotive members; both the first pair, which may be compared with the pectoral extremities of the vertebrate animal, and the last pair, which are analogous to the pelvic members, as well as the middle pair, to which there is no correlative in the vertebrate series. This centre of the locomotive powers is divided into three segments, which correspond with the three pairs of legs: the first segment is termed the "pro-thorax" (*d*), the second the "meso-thorax" (*f*), and the third the "meta-thorax" (*i*). Each of these segments has a dorsal and a sternal piece: the dorsal half-rings are called respectively "pronotum," "mesonotum," and "metanotum;" the ventral or sternal arcs bear the corresponding terms, "prosternum," "mesosternum," and "metasternum." From the inferior arches of the segments, the legs (*e, h, k*) are developed, or with them they are principally articulated, like the legs of the Crustacea and the ventral oars or setigerous prolegs of the Anellides. In the flying Insects there are developed from the dorsal arches of the middle and third segments, locomotive appendages which constitute the wings (*g j*).

It must not be supposed that the parts of the thorax which have just been described are naturally or uniformly separate, and moveably connected with one another; they are more commonly confluent, but in different degrees in different families, so as more or less to obscure the primitive traces of their original distinctness, which can only be demonstrated, as has been done by Macleay, Audouin, Burmeister, and others, by an extended comparison of the thorax in the whole class of Insects, or by tracing its development and modifications during the various stages of the metamorphoses. When the composition of the thorax of an Insect is thus studied, it is found to be made up of not less than fifty-two pieces, which have for the most part received, and necessarily, distinct names in Entomology, and many of them, very unnecessarily, more names than one.

The abdomen is usually formed of a greater number of segments, always nine in the larva, which retain a greater degree of mobility upon each other; but it supports no locomotive appendages in the Hexapod Insects.

The tissue of the external skeleton is of a dense, resisting, but light material; it looks and feels like horn, but it has for its base a peculiar substance called "chitine," which, like the "cellulose" of plants, is insoluble in caustic potash, and retains its form like charcoal when submitted to a red heat; but it contains nitrogen. The articulated appendages consist, like the segments of the trunk, of hollow cases or tubes of the same firm and slightly flexible substance; which tubes contain the muscles, nerves, and other soft parts in their interior. The integument is softer and more yielding in larvæ, flies, and most parasitic insects: it is thickest and hardest in the burrowing beetle tribe, in which the flexible property is limited to the joints of the segments and their appendages. Uncalcified chitine is always more or less elastic, and no tissue could be better adapted to enable a light flying animal to resist external violence than that which constitutes the seeming horny case of Insects. It consists of three layers, epidermal, pigmental, and dermal; the derm and epiderm more closely resemble each other in physical properties than in other animals: they are separated and cemented together by sometimes two distinct coloured layers of rete mucosum; but the pigmental matter is often combined with the dense chitine. The hairs, spines, and scales are processes of the epiderm, which often include a coloured substance: the bulbs of the hairs are imbedded in the movements, may be termed arthrodial. In Insects of flight, the cavity of the thorax is almost entirely occupied by the muscles of the wings. There are two extensor and several small pairs of flexor muscles, which arise from the meso- and meta-thorax, and are inserted into a process at the base of each wing. The muscles of the legs have similar fulcral processes, but longer, like tendons; they are, however, chitinous apodemata of the external skeleton. The muscular fibre is transversely striated, and is also characterised by a second series of transverse indentations at regular but wider intervals.

The wings of Insects are essentially flattened vesicles, sustained by slender but firm hollow tubes called "nervures," along which branches of the tracheæ, and channels of the circulation, are continued. The wings never exceed two pairs, which are developed from the mesonotum and metanotum. Sometimes one or other of these pairs is wanting. The wings present many varieties in their shape, their consistence, and their teguments. When they subserve flight, they are thin and transparent; or, if opake, are rendered so by an imbricated clothing of most delicate scales, which, when detached, resemble the pollen of flowers. In certain insects, especially those that burrow, the first pair of wings become thick, hard, and opake, forming a kind of shield to the back; they are called "elytra," and cover the posterior pair of membranous wings when these are not expanded for flight. Sometimes the anterior wings are membranous at their extremities, hard and opake at their base, when they are called "hemelytra," When the hinder pair of wings is wanting, it is replaced by a pair of rudimental appendages called balancers: other modifications of, or appendages to, the wings have been called "alulæ" and "patagia."

The Orders of Insects being, as before remarked, founded upon the modifications of the wings, the chief of these are best exemplified by recapitulating the ordinal characters. Those Insects in which the first pair of wings are hard, inflexible, and serve as sheaths (elytra), and the second alone are used for flight, and are folded transversely when at rest, constitute the order *Coleoptera:* these insects undergo complete metamorphosis, and are subdivided according to the number of joints of the tarsi. Beetles and most burrowing Insects belong to this order.

Those Insects in which the anterior pair of wings are converted into elytra, of less density than in the *Coleoptera*, and in which the posterior wings are folded longitudinally when at rest, constitute the order *Orthoptera:* they are said to undergo a semi-metamorphosis, the chief change being the acquisition of wings. This order includes the most voracious and destructive insects, as the Locust, Cockroach, &c.

Those insects which have both pairs of wings membranous, transparent, strengthened by numerous nervures, and finely reticulated, form the order *Neuroptera*, which includes the highest organised insects, as the predatory dragon-flies.

The insects which have four membranous wings simply veined, and crossing each other horizontally when at rest, form the order *Hymenoptera:* they undergo a complete metamorphosis, and include the most useful of insects, *e. g.*, the bee.

The insects with four wings, more or less clothed with minute scales, are called *Lepidoptera:* they undergo complete metamorphosis, and include the most beautiful species of the class, as the butterflies: in one family of this order the wings are divided lengthwise into a number of feathered pieces, which radiate from the body like the stems of a fan (*fig.* 143).

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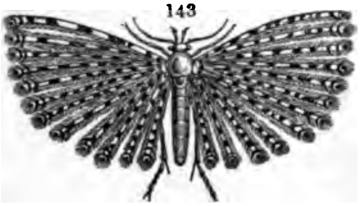

Pterophora.

The insects which have the anterior pair of wings in the condition of the hemelytra, form the order *Hemiptera;* but certain genera have the dense part of the anterior wings reduced to so small a strip, that they are scarcely distinguishable, except by size, from the posterior pair, and these insects constitute a section of the order termed *Homoptera.*

A few remarkable genera of insects have the anterior pair of wings reduced to small or rudimental elytra, and the posterior pair unusually large, and folded longitudinally, like a fan when at rest. The anterior wings being reduced to minute appendages twisted spirally, the Order has been hence termed *Strepsiptera.* The species, in their larval state, are parasitic on the bee tribe.

The order *Diptera* is characterised by the development of the anterior pair of wings into organs of flight, and the retention of the hinder pair in the condition of minute clavate appendages, usually called the "balancers." The prothorax and metathorax are rudimental whilst the mesothorax is disproportionately large to form the required space for the powerful muscles, which execute, through the two anterior wings, the function of flight.

In almost every Order of Insects there are species, or there are individuals, as the females of particular species, which are apterous; but since the time of Aristotle, who divided insects primarily into the "winged," *Ptilota*, and the "wingless," *Aptera*, most of the hexapod insects devoid of wings have been artificially grouped together. Cuvier and Latreille divide the Apterous Insects into three tribes, the *Suctoria* (fleas), the *Parasita* (lice, including the *Pediculus capitis* and *Pthirus inguinalis* of the human species), and the *Thysanoura*, including the *Lepisma* and *Podura* or skip-tails.

The grand and characteristic endowment of an insect is its wings; every part of the organisation is modified in subserviency to the full fruition of these instruments of motion. In no other part of the Animal Kingdom is the mechanism for flight so perfect, so apt to that end, as in the class of insects. The swallow cannot match the dragon-fly in its aerial course; this insect has been seen to outstrip and elude its swift pursuer of the feathered class: nay, it can do more in the air than any bird,—it can fly backwards and sidelong, to right or left, as well as forwards, and alter its course on the instant without turning.

Now what are these "limber fans," that give the little articulate animals such command over aerial space? I do not mean their structure or composition; the anatomical question has been already answered. I do not ask for their analogy; that is rightly expressed by their common name; they have the same relation to the insect as instruments of motion, which the feathered wing bears to the bird. But what is their essential nature, or with what are the wings of the insect homologous? Are they modified anterior limbs, like the wings of bats and birds and flying-fishes? Not so, for they co-exist with and are superadded to the jointed anterior pair of legs. Are they such expansions as form the parachute of the little dragon (*Draco volans*)? These do, indeed, co-exist with arms and legs, but they consist of a fold of integument stretched out upon elongated and straightened ribs, which are appendages of a vertebral column. But an insect has no vertebral column, no true internal skeleton. The strong and numerous nervures which sustain the thin alar membranes of the Libellula are articulated processes of the external chitinous tegument.

A circulation can be traced through these membranes, at least in their early and softer state; air-vessels are abundantly spread over the supporting frame-work: the wings of the Lepidoptera appear after the third moult, as tegumentary flattened vesicles, soft, and permeated by tracheæ, and when fully expanded in the imago, they must still take their share in the business of respiration. Nay, it has been found that the rudimental wings of the pupæ of certain water insects are the gills of such; they perform the same function as the very similar membranous and vascular tegumentary expansions in certain Anellides (see *fig.* 101,); which expansions are developed, as in the larvæ of the Ephemera, from the tergal arch of the segment, and co-exist with rudimental legs from the ventral arch of the same segment.

Well, therefore, has the deep-thinking Oken* called the wings of insects "aerial gills;" they are, in fact, the homologues of the tergal branchiæ of the vermiform Articulata, raised to a higher function in correlation with a generally transmuted state of the rest of the organisation, which is advanced to the utmost perfection of which the Articulate type of structure is susceptible. And have we not already seen the membranous aliform branchiæ of the beetle protected, like the gills of the lobster, by an elytral carapace developed from a more advanced segment? Have we not likewise found the metamorphosed branchial wings of the Pterophora subdivided lengthwise like the tufted tergal gills of the Nereis?

The air-breathing articulated animals with jointed legs offer a close correspondence with those that respire by gills in the progressive steps of complication of the nervous system and the order in which those steps succeed each other. The lowest insects, like the lowest Crustaceans, resemble the worms, in the great length and slenderness of their body, and in the uniform size, shape, and number of the constituent segments. In the Iulus (*fig.* 140.), whose very short and numerous rings support each two pairs of rudimental legs, the corresponding ganglions of the abdominal chords are much less conspicuous than in the earth-worms, and the whole central axis of the nervous system, continued from the brain, is almost as devoid of partial swellings as the spinal chord of the apodal vertebrate. It lies, however, as in other Articulata, on the opposite side of the body to that in which the brain is situated.

The cephalic ganglion (*fig.* 144, *a*) of the Iulus is transversely elongated, and obscurely divided by a slight median indentation into two side-lobes: its upper and latter extremities are prolonged outwards into the short and thick optic nerves (*c*, *c*), which resolve themselves half way towards the compound eye into a plexus of filaments for its several divisions. Two separate antennal nerves, conjectured by Straus to be motory and sensory (*d*, *d*), are sent off on each side below and in front of the optic nerves to the short seven-jointed antennæ. On each side also, but below the antennal nerves, arise the two nerves (*b*) united together by an anastomosing branch which supply the palpless mandibles.

The thick œsophageal chords (*g*) are continued from the posterior and inferior angles of the brain; and, though apparently simple, consist essentially of two chords, which become separate at the lower part of the pharynx: the anterior chord girts the pharynx by a transversely oval ring, formed by its confluence with its fellow; the posterior and normal columns converge at an acute angle backwards, blend together, and expand into the commencement of the abdominal nervous trunk; thus inclosing the œsophagus by a second and looser collar. The closer anastomotic ring is homologous with that formed by the transverse commissural band of the œsophageal chords in the lobster and limulus; and probably also to the anterior nervous ring discovered by Lyonnet in the Cossus ligniperda. The stomato-gastric nerves which arise from the posterior part of the brain immediately form a third slender ring (*e*), about the œsophagus, from the middle of the upper part of which the trunk of the stomato-gastric system (*f*) is continued a short way back upon the stomach, when it divides; the two divisions diverge at an angle of 45°, bend abruptly backwards, and run parallel with each other along the dorso-lateral parts of the wide and straight alimentary canal.

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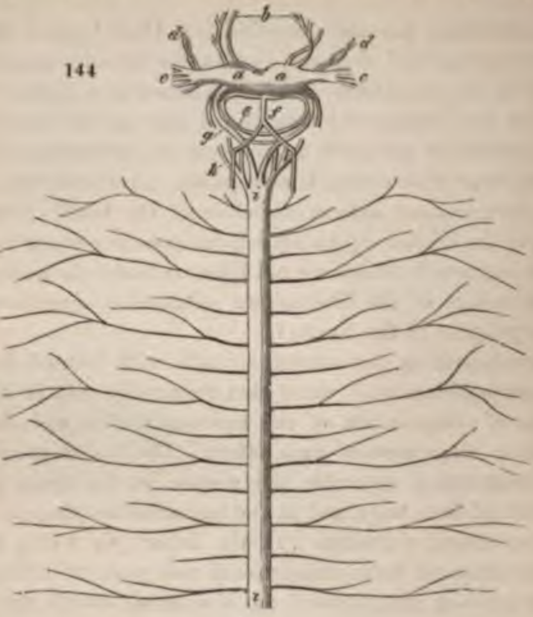
* Natur. Philosophie, 2d Ed. p. 418.

144

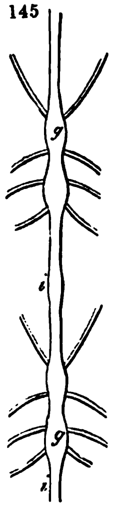


Iulus.

Two large nerves (*h*) are sent forwards from the beginning of the thick subœsophageal or ventral chord (*i*, *i*), to supply the confluent maxillæ, which form the under lip: the nerves of the two single pairs of feet, belonging to the thoracic segments, next arise, and afterwards the more numerous minute nerves to the little feet, which, by their articulation to the segments in double pairs, indicate such segments to be severally a confluence of two. The simplicity of the abdominal chords corresponds with the close approximation and great numbers of the organs from which they receive impressions and to which they transmit stimuli. The analogy of this exceptional condition of the abdominal chord or nervous axis in the Iulus to the dorsal spinal chord of the Vertebrata, is as instructive as is that of the equally exceptional ganglionic condition of the spinal chord in the Tetrodon amongst fishes to the normal abdominal knotted chords in the Articulata, in tracing their mutual relations to each other.

The segments of the Polydesmus are relatively fewer and larger than in the Iulus, and their lateral margins are produced: each, however, with the exception of the first three, which answer to the thorax in hexapod insects, supports two pairs of legs: but these are longer than in the Iulus. Accordingly we find the sub-abdominal nervous chords (*fig.* 145, *i*), which show as little trace of their median separation as in the Iuli, swelling into two slight enlargements (*g*, *g*) opposite each of the abdominal segments: two nerves are sent off from either side of each enlargement, and the anterior of these four pairs of nerves is directed at an acute angle forwards and outwards to the stigmata: the remaining pairs supply the muscles of the segment and the legs, and are of equal size.

145



Polydesmus.

In the Centipede, a series of equal and equidistant ganglia is developed upon the ventral surface of the two abdominal chords. Only in the first and last of the abdominal ganglions can any modification of size be detected. The anterior, or sub-œsophageal ganglion, for example, is larger than the rest, having to supply the modified legs which perform the function of jaws and under lip; the chords, diverging as they escape on each side of the œsophagus, enclose it by uniting with the large bilobed ganglion, or brain above. The nerves from this part supply the large antennæ and the aggregated ocelli. In the structure of the abdominal columns a tract less closely connected with the ganglionic nerves may be traced along their dorsal aspect. This was first pointed out by Mr. Newport, who attributes to it the motor function. A large, vascular trunk, connected also with the dorsal aspect of the nervous system, has been regarded as part of the nervous system; by some as a motor, by others as a respiratory column: its true nature was detected by Mr. Lord.* With regard to the ganglionic and nonganglionic portions of the true nervous axis, the same physiological reasonings will apply as have led to the conclusions already given respecting their office in the crustaceous animals.

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* Med. Gazette, March 3d, 1838.

Of the four nerves which come off from the sides of the ganglionic portions of the columns, the second, which is principally distributed to the muscles of the corresponding pair of legs, arises in a great proportion from the ganglion itself. The first and third nerves, which are smaller than the second, supply the muscles and integuments of the segment. The fourth pair of nerves passes to the breathing pore and to the integument. This, therefore, must be regarded as the respiratory nerve. The stomato-gastric nerve is a distinct system connected with the anterior ring or brain.

Thus in the Myriapodous insects we find that although the principle of irrelative repetition prevails in the nervous system as in the skeleton and locomotive instruments, yet it does not prevent the recognition of the leading physiological divisions of that system. We have, for example, the super-œsophageal or cephalic portion, which is subservient to the functions of the special organs of the senses, and is the centre whence voluntary impulse may be directed along the nonganglionic tracts of the nervous axis, and to which ordinary sensation may be transferred by similarly uninterrupted nervous filaments. We have, secondly, a large sub-œsophageal mass, which, originating the nerves analogous to the fifth pair, for the masticating organs and other parts of the head, may be regarded as analogous to the medulla oblongata. In the abdominal chords and ganglions we have the requisite machinery for the automatic reception and reflexion of stimuli, independently of sensation and the will; and to these are superadded intercommunicating and uninterrupted chords, for bringing the body under the dominion of the will, and for producing harmony and consent of action throughout its extent. The special nerves to the respiratory system, and the stomato-gastric nerves, complete this already complicated nervous system.

In the hexapod insects the nervous system differs chiefly from that in the Myriapods in having its primary divisions more definitely developed, and in manifesting degrees of concentration corresponding with the increase of bulk and strength of particular parts of the trunk, and in the locomotive organs appended thereto. Most insects, however, commence their career as worms; the high form which they are ultimately destined to attain in the articulate series is at first masked by the guise of an Annelid or Entozoon. Some insects retain their larval or vermiform state much longer than others; and after passing a great proportion of their lives under this form, fall into the state of the pupa, or chrysalis,—relapsing, as it were, a second time into the condition of an ovum,— there and then undergoing that part of their development which before was left incomplete: finally they emerge in their perfect state to enjoy for a brief period the highest faculties, animal and organic, which they are destined to acquire; fluttering in the air, it may be, for a single day, procreating their kind, and perishing. Now the development of the nervous system, like that of the muscular, digestive, and other systems, being completed at distinct and sometimes remote periods, requires to be studied in the first and last of the active states of the insect, and also in the intermediate period, when, owing to the rapidity and extent of the changes which it undergoes, the nervous system offers to the comparative anatomist and physiologist phenomena of the highest interest.

The apodal entozoiform larvæ, in which the segments of the body are obscurely defined, as those of most Diptera, Hymenoptera, and of some Coleoptera with very rudimental feet, have a simple ventral nervous chord, almost as devoid of ganglionic enlargements as in the Nematoidea and Iulidæ: it is, however, usually relatively shorter, failing to reach the posterior extremity of the body, and the fine nerves pass off on each side and radiate from the extremity.

In the larva of *Stratiomys chamæleon* the ventral chord is divided by a series of constrictions into eleven consecutive and contiguous ganglia.

The larvæ, which present, like the Centipede, larger and more definite segments, most of which are provided with legs or prolegs, have a ganglionic centre for each segment, and intermediate chords.

This anellidous and chilopodiform type of the nervous system has been best described and figured by Lyonnet.* The subject which this inimitable dissector and artist selected for his patient investigations was the caterpillar of the *Cossus ligniperda.* The nervous axis consists of thirteen ganglions, arranged along the median line of the body, and connected by two chords or columns. The first and largest ganglion, situated in the head above the mouth, and of a bilobed form, Lyonnet calls the brain; the remaining twelve ganglions (as in *fig.* 159, 1 to 12.) are situated below the alimentary canal; the eleventh and twelfth are so close together that their distinction might readily be overlooked; but it was pointed out by Lyonnet. The sub-abdominal ganglions and inter-communicating chords were called by Lyonnet the spinal marrow. Some anatomists who have applied the analogy of the ganglionic and non-ganglionic roots of the spinal nerves in the higher Vertebrata to the explanation of the functions of the ganglionic and non-ganglionic parts of the nervous axis in Insects, have thought the ganglionic and nonganglionic portions of the true nervous axis, the same physiological reasonings will apply as have led to the conclusions already given respecting their office in the crustaceous animals.

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* CCXL.

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* CCXL.

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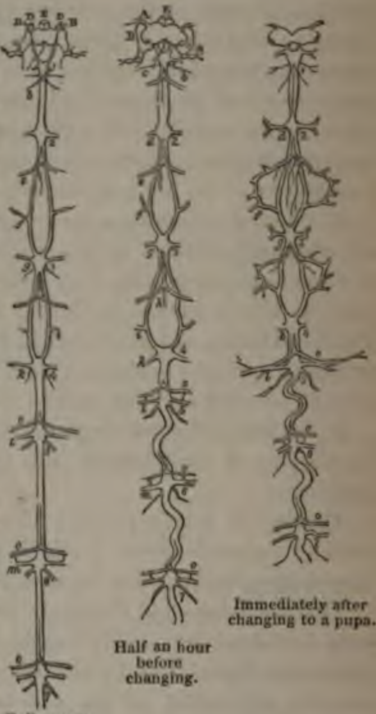

Full-grown Larva.

Half an hour before changing.

Immediately after changing to a pupa.

Vanessa urticæ.

"The spinal marrow of the caterpillar, if one may say that it possesses such," observes Lyonnet, "sensibly differs from that of man. It is slender; it bifurcates at intervals, and enlarges from distance to distance to form its masses, which I have named ganglions." The intervening chords Lyonnet terms "conduits de la Moelle épinière." He particularly points out the difference in relative position, and in the means of protection assigned to the ganglionic columns in insects, and to the spinal chord in the higher animals. As to any views of distinct physiological properties in the ganglions or the non-ganglionic nervous tracts, none such appear in the works of Lyonnet; nor, indeed, did they form part of the domain of physiology at that period; and it was a great advantage to Zootomy that Lyonnet looked at his subject with the eye of truth, and not through the prism of any pre-formed physiological notions.

The super-œsophageal ganglion gives off ten nerves; eight in pairs, and two solitary or azygos nerves; one of these latter is the anterior œsophageal ring (*fig.* 146, E). Its extremities are connected with the cephalic ganglion immediately anterior to the attachment of the principal columns which form the posterior œsophageal ring. The second solitary nerve (*c*) is sent off from the middle of the posterior side of the cerebral ganglion, and proceeds backwards to the œsophagus. The cephalic nerves, sent off in pairs (B, B), supply the antennæ, the ocelli, the muscular and integumentary parts of the head, and communicate with branches of the maxillary nerves. The most remarkable pair, however, is that which arises anterior to the annular or œsophageal nerve, and which constitutes the cephalic roots, or connections of the stomato-gastric system. Each of these nerves passes forwards and divides: the external tract joins one of the maxillary nerves of the sub-œsophageal ganglion; the internal one converges towards its fellow, and terminates with it in the first of the median cephalic series of ganglions (E), which Lyonnet terms frontal ganglions. The longest nerve in the whole body of the caterpillar is given off from these ganglions as it passes along the œsophagus to the stomach and intestines: it was called by Swammerdam the recurrent nerve. There are two other small ganglions situate in the head of the caterpillar on each side of the large bilobed or cephalic ganglion (*a*, *a*). The largest nervous columns connected with the super-œsophageal ganglion, are those which enclose the œsophagus by uniting with the first of the lower series of ganglions (1). From this ganglion nerves are distributed to the mandibles, the maxillæ, the lips, and their special organs of sensation or palpi. Two distinct columns connect the first with the second ventral ganglion (2); and this is connected by more diverging columns with the third (3). The inter-communicating chords of the remaining ganglions appear single at their anterior part, and bifurcate as they are connected with the next ganglion in succession. They are of a greyish blue but transparent colour, and are very elastic. From each side of the abdominal ganglions are given off two principal branches; the anterior to the muscles chiefly, the posterior chiefly to the integuments, but communicating with the muscular branch of the succeeding ganglion. From the beginning of the separation of the bifurcated inter-ganglionic columns, or conduits, Lyonnet says, "there descends a nerve, the extremity of which is enlarged a little above the succeeding ganglion, which sends off from the enlargement a transverse nerve to the right and to the left, to which I give the name of spinal rein (bride épinière, *o*, *o*). Of these transverse nerves there are ten pairs; they terminate chiefly in the stigmata and tracheæ, but send off small branches to the skin, and to the dorsal vessel. These are the respiratory ganglia and nerves, and have been erroneously considered as the motor column and nerves.

The nervous system in perfect insects approaches to its larval condition according as the segments of the body and their locomotive appendages are less concentrated and developed; thus, in the darkling beetle (*Melöe*) the abdominal nervous columns still manifest eight distinct ganglions, of which the last, perhaps including three ganglions of the larva, is now the largest, and radiates its branches to the generative organs. The sub-œsophageal ganglion sends forward four median branches to the under parts of the mouth, and is connected with the super-œsophageal ganglion by the two lateral chords forming the post-œsophageal collar. The usual nerves are given off from the brain; those to the eyes having acquired an increase of bulk, corresponding with the great change in the size and complexity of the organs of vision. The stomato-gastric nerves arise close to the antennal branches, and form a median frontal ganglion, and are connected with a pair of lateral ganglions: from these the usual recurrent nerve is given off. In the thorax we distinguish the second ventral ganglion, which, as it distributes branches to the first pair of legs, I have called the brachial ganglion. The third ventral ganglion, supplying, amongst other parts, the elytra, may be termed the elytral ganglion. The fourth ventral ganglion is distinct in the present species, and, supplying the nerves to the second or true wings, may be termed the alar ganglion. The fifth, sixth, and seventh, or first three ganglions in the abdomen, distribute nerves to as many large and moveable segments of that division of the trunk: the last ganglion is the largest, and its size is conformable with the bulk of the generative apparatus, upon which, on the rectum, and the modified terminal segments of the abdomen, its branches are expended.

In insects having the organs of flight better developed, the elytral and alar ganglia present a greater proportional size; but different degrees of concentration in the centres of the nervous system are met with in these higher forms of insects. In the Blattæ, for example, there are as many as ten distinct ventral or inferior ganglions. The super-œsophageal nervous centre or brain is a transversely oblong bilobed mass, sending its upper and largest pair of nerves to the eyes. Anterior and below, the antennal nerves arise from small mamillary processes of the brain, reminding us of olfactive lobes. The stomato-gastric nerves are seen a little in advance of those in the deflected part of the head. The œsophageal chords are short, uniting in a maxillary ganglion, or first of the ventral series, which is situated in the head; the inter-communicating chords, which pass from this to the brachial ganglion, are long, straight, parallel, and juxta-posed. The brachial ganglion sends off two large and two small pairs of nerves; the anterior ones are distributed to the muscles of the arm, which are lodged within the anterior portion of the thoracic shield; the second nerve is continued to the terminal segment of the anterior extremities like the second nerve from the ganglions of the centipede. The elytral ganglion, or the third of the ventral series, is larger than the preceding one. Viewed from the dorsal aspect, it is seen to distribute three small nerves to the muscles of the wing-cover; the posterior branch, anastomosing with the nerve sent from the succeeding ganglion to the wing, thus serves to combine these organs of flight in action in the Orthopterous insects. In the Coleoptera, whose elytra do not move in flight, this anastomosis of the nerves does not take place. Four pairs of nerves come into view when the elytral ganglion of the cockroach is exposed from below. The anterior of these runs forward at an acute angle to the muscles of the first and second pairs of legs. The next two anastomose with an alar branch. The third pair enters the second pair of legs, and is distributed to their terminal segments. The posterior nerve passes to the alar plexus. The substance of the bilobed elytral ganglion seems to be superadded to the under or ventral part of the nervous chord. The alar ganglion, formed by a confluence of the fourth and fifth of the larval ganglions, is situated at the same distance from the elytral as this is from the brachial ganglion. It is not quite so broad as the elytral ganglion, the wings which it supplies being shorter than their covers. The anterior nerve enters into communication with the elytral branches, as does also the second nerve, with the addition of branches to the muscles of the legs. The third nerve is distributed to the third pair of legs; the fourth to the muscles of the wing. The remaining six ganglions of the ventral series are contained in the abdomen: they are smaller than the preceding, the distance between them progressively increasing after the third. The last, formed by the confluence of the eleventh and twelfth ventral ganglions of the larva, is of a triangular form, and the largest of the series. It sends off a pair of conspicuous nerves to the cercæ or anal antennæ. The two interganglionic columns are in contact lengthwise from the head to the anal ganglion. In the Meloë they are smaller, and separated by a marked interspace. The respiratory nerves may be seen on the dorsal aspect above the second, third, and fourth ventral ganglion. If the nervous system of the Blatta be compared with the stages of development of that system in an insect presenting a more concentrated type in the perfect state, as in the species of butterfly described by Herold*, it will be found to correspond with the sixth stage figured by this author in the pupa of the *Papilio brassicæ.*

In the predatory leaf-insect (*Mantis*) the progress of coalescence has reduced the number of abdominal ganglia to four, the three thoracic ganglions continuing distinct, so that the nervous system corresponds with the eighth stage figured by Herold in the Lepidopterous insect just mentioned. The super-œsophageal mass consists of two triangular lobes having their bases rounded and anterior, and their apex prolonged into the œsophageal chords. Two small nerves are sent off from the anterior part to the ocelli, where they swell into a slight enlargement. Two short and thick optic nerves pass from the sides of the brain to form the ganglions supplying the large compound eyes. The stomato-gastric nerves arise, one on each side, near the optic nerves. The œsophageal columns are short, and directly converge to the inferior cerebral ganglion, which gives two large and several small nerves to the jaws: it is situated in the head. Two g and parallel columns extend to the first thoracic ganglion, which ransmits long and large nerves to the formidable prehensile anterior pair of legs. The second thoracic or elytral ganglion is at a great distance from the first, and much nearer the third or alar ganglion. Anastomosing branches connect the nerves which these ganglions pectively distribute to the elytra and wings. The Mantis is efly remarkable for the great length of the ventral chords conecting the brachial with the elytral ganglia, and which renders m favourable for minute analysis of their structure. Anterior d posterior columns, or divisions analogous to those in the spinal marrow of higher animals, cannot be distinguished. The so-called orial tract is confined to accumulations of nervous matter at the in of the nerves to the locomotive organs.

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* CCXLI.

Experiments in which the body of the living Mantis has been so divided that a segment with one of these ganglionic enlargements nd the locomotive organs it supplies has been detached from the rest, illustrate the functions of the aggregated centres of nervous matter in relation to their power of receiving and transmitting impressions, so as to maintain the order of action of such detached organs upon the application of a stimulus, for a considerable period after the mutilation.

The jaws of the separated head of a Mantis bite forcibly the stick which is held to them. The formidably armed prehensile legs in like manner wound the finger that touches them, when the segment of the body supporting them is separated from the head and the rest of the trunk. And if decapitation or amputation of the prothorax be neatly performed on the living insect, while in its natural and ordinary position, perched by its middle and hinder pairs of legs upon a twig, the rest of the trunk does not fall to the ground, but is maintained for a certain period in that posture, which it even recovers by actions of the wings, when the balance is slightly and purposely disturbed.

The super-œsophageal or cerebral mass in insects obtains its largest development in the dragon-fly (*Libellula*), which from the size and perfection of its organs of vision, its great and enduring powers of flight and predatory habits, may be regarded as the eagle of insects. From the side of each of the superior lobes of the brain, the optic nerve is continued of equal breadth, so as to seem rather as a lobe of the brain. It expands, and, like the stalk of a mushroom, forms the stem of a very large reniform ganglion, the convexity of which is turned forwards and outwards, and the free concave projecting margin developed at the under part. Thousands of branches to the divisions of the compound eye are given off from the convex surface of this ganglion. The brain presents a single median inferior lobe; the œsophageal chords sent downwards to the maxillary ganglion are short and thick. This ganglion is succeeded by three large equidistant thoracic ganglia, of which the last two, corresponding with the elytral and alar ganglions of the preceding insect, are, as might be expected, from the development of the muscles of the wings (both of which are alike organised for flight), considerably the largest. Of the ganglia of the abdomen, the terminal one resulting from the confluence of two, and which supplies the organs of generation, is remarkable for its large size.

In the white butterfly (*Papilio brassicæ*) the brain is a thick transverse rounded mass, indented by a longitudinal furrow along the median line. From its sides proceed the large optic nerve, now greatly surpassing the other cerebral nerves in size. The œsophageal collar is triangular, leaving a very small interval for the passage of the alimentary gullet. The maxillary ganglion is relatively much smaller than in the dragon-fly, the blatta, and other mandibulate insects. The first two thoracic ganglions are blended into one, and the third thoracic and first abdominal ganglions have coalesced to form a similar mass in the thorax, connected with the preceding by short chords, separated by an interval to allow the passage between them of certain processes of the thorax giving attachment to the muscles of the legs. The ganglions of the thorax have been observed in some species (as the *Bombyx Neustria*) to present a reddish tint. They are succeeded in the Lepidoptera by four other ganglions in the abdomen, of which the last, as usual, is the largest.

The nervous system of the chaffer (*Melolontha*) has been dissected and delineated by Strauss* with a minuteness and accuracy second only to those of Lyonnet. In his beautiful plates are shown the bilobed brain with its auxiliary ganglia for the eyes and antennæ; the stomato-gastric nerves and their small lateral cephalic ganglia are also clearly exhibited. The sub-œsophageal or maxillary ganglion is of an oblong form; the brachial ganglion is triangular; the elytral ganglion is of a circular, and the alar ganglion of a pyriform, figure; these two latter being concentrated into almost a single mass, and snout in suctorial insects, the long and slender ovipositors of insects which place their eggs in holes of various depths, the soft, setaceous, or plumed antennæ, and above all, the palpi, often provided with a terminal vesicle, present the requisite physiological conditions of the organ of touch. Although another sense, and most probably that of hearing, may reside in the antennæ, yet no one can witness the use of these organs by bees and ants, the exploratory actions of those of the ichneumon and of many other insects, without recognising in them instruments of the tactile faculty.

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* CCXLII.

All Mandibulate insects have a process from the labium, within the mouth, so analogous to a tongue as to have received that name. It is particularly well developed in the wasps (*Vespidæ*), the dragon-flies (*Libellulidæ*), the grasshoppers (*Locustidæ*), and certain beetles (*Carabidæ*), in which its soft, finely ridged, upper surface receives a rich supply of nerves. It is not present in the suctorial insects, which, as Burmeister well observes, always subsist upon one and the same food, generally inhabit what they feed on, and consequently less require the sense of taste.

Although a few physiologists have suspected that some part or appendage of the head, and others that the membranous lining of the spiracles were the organs of smell, the precise seat of that sense, which unquestionably exists in insects, has not yet been experimentally determined. The application by the common house-fly of the sheath of its proboscis to particles of solid or liquid food before it imbibes them, is an action closely analogous to the scenting of food by the nose in higher animals: and as it is by the odorous qualities much more than by the form of the surface, that we judge of the fitness of substances for food, it is more reasonable to conclude that in this well-known action of our commonest insect, it is scenting, not feeling, the drop of milk or grain of sugar. But no one ever saw an insect present its spiracles to a nutritive substance before feeding.

The signs of attention and hearing are plainer in insects than those of smelling; yet the precise organ has not yet been more definitely recognised, unless the structure indicated by J. Müller* in the fore-leg of the *Gryllus hieroglyphus*, and more definitely described by Siebold† in other Orthoptera, be the true seat of the auditory sense. Between the pro- and meso-thorax of the grasshopper and cricket is a double pair of stigmata; one of each pair is conspicuous by its large oval unlabiate aperture, which leads to an infundibular trachea; close to this large aperture is the second stigma of the ordinary size and shape; the tracheæ from this stigma ramify in the prothorax and head; but the infundibuliform trachea sends off no branches in its course through the prothorax. Pursuing this trachea from the infundibular beginning backwards to the coxa of the anterior feet, we see that here it sends off various larger and smaller branches, but enters the limb without material diminution of calibre. In traversing the slender knee, the trachea is obliged to contract; but it soon again expands, and forms at the part of the tibia of the first pair of legs, where the two folds and apertures are seen, a long vesicular dilatation of a peculiar form. This vesicle is in connection, externally, with a tympanic membrane closing an orifice in the leg, and internally with a peculiar part of the nervous system. Two nerves, both derived from the first thoracic ganglion, and both unusually large, accompany the trachea down the leg: the lesser nerve attaches itself to the vesicular dilatation, and there expands into a flattened ganglion, on which is situated a row of transparent vesicles containing a collection of cuneiform, staff-like bodies, with very finely pointed extremities, which are surrounded by ganglion-cells. An undulated prolongation of the ganglion is thence continued, and is lodged in a depression on one side of the vesicle. The aperture in the leg is compared to an external ear; the membrane closing it and the chamber behind, to the tympanic cavity and drum; the nerve and ganglion to the acoustic nerve; and the thoracic aperture to the Eustachian tube. It is strange, however, that the organ under so well marked a form should not exist in the tree-hoppers (*Cicadæ*), which attract their females by peculiar notes. In these *Homoptera* the soft capsular membrane of the joint of the antenna, which in some movements may be rendered tense, has been alluded to by Burmeister as a structural indication of the organ of hearing in the peculiar appendages in which he supposes, with many other entomologists, that the sense resides. Two, at least, and often more numerous, nervous filaments from a slight ganglionic enlargement penetrate the antennæ in insects; and these may subserve the distinct offices of the appreciation of the vibrations of sound, of the characters of surface, and of the regulation of the movements of the antennæ.

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* CCXLIV. p. 439.

† CCXLV. p. 56—72, tab. I.

Of all the organs of the special senses not only is that of sight manifest without ambiguity, but it is more complicated and relatively larger in insects than in any other class of animals.

What would be thought of a quadruped, whose head, with the exception of the mouth and the place of juncture with the neck, was covered by two enormous convex masses of eyes, numbering upwards of 12,000 in each mass? Yet such is the condition of the organs of vision in the dragon-fly, which, besides the two great compound eyes, ris, in the narrow interspace on the vertex of the head, three simple eyes, called ocelli and stemmata.

In all insects the eyes are sessile, or, if supported, as in a few rare instances (*Diopsis*, e. g.), on prolongations of the head, such peduncles not moveable like those which support the compound eyes of the her Crustacea. The eyes are either "simple" or "compound:" first are found in the larva, the second in the imago of hexapod insects; in some of the latter both kinds occur. The blind exceptions in the class are few; such are certain species of *Ptilium* that live ler the bark of trees, the *Claviger*, which dwells in ants' nests, and the *Anophthalmus*, peculiar to dark caverns. The larvæ of *Hyme-* and *Diptera*, and most of the apodal larvæ of *Coleoptera*, nd.

A simple eye (*ocellus, stemma*) is composed of a cornea, behind ich is a spherical or cylindrical lens, lodged in a kind of calyx med by an expansion of the optic nerve, and which is surrounded a layer of diversely coloured pigment.

There is only one ocellus on each side of the head in the lice *iculidæ*, *Nirmidæ*), cochineal insect (*Coccidæ*), and the larvæ of the *Phryganidæ*. The ocelli are in groups of four to eight in the skiptails (*Poduridæ*), the hexapod larvæ of the *Strepsiptera* and *Coleoptera*, the larvæ of *Lepidoptera*, *Hemerobidæ*, *Myrmelionidæ*, and *Raphidiidæ*.

The Centipede has many simple eyes, arranged in a cluster on each side of the head, and requiring only a little closer approximation to form a compound eye. The required approximation takes place in the Iulus, but the optic nerve, instead of swelling into a ganglionic mass, separates into a pencil of nerves at the base of the cluster, one for each ocellus. The transition to the large compound eye of the hexapod is made by the Iulus and Scutigera; but the interval is very wide between the Myriapods and Anellids in regard to both the number and structure of the organs of vision.

The lateral compound eyes of winged insects are generally circular, sometimes oval, or reniform; they occupy the sides of the head, and sometimes encroach upon the upper part so as to meet there. In some Capricorn beetles, as *Tetraopes*, the antennæ project from the middle of the ovate eyes and divide them into an upper and lower half: the compound eyes of certain beetles of the genera *Ateuchus* and *Geotrupes* are almost or quite divided into two on each side by the encroachment of the canthus; some *Ephemeræ* and the *Gyrinidæ* have two pairs of compound eyes: in the latter they are situated one on the upper, the other on the lower surface of the head, and must serve the aquatic whirligigs to discern at the same time objects beneath them in the water, and above them in the air.

The integument of the head, which passes uninterruptedly over the compound eye, there becomes transparent, and is subdivided into a number of hexagonal corneules, varying in number from 50 in the ant, to 4,000 in the house-fly, to above 17,000 in the butterfly, and to more than 25,000 in the Mordella beetle. The size of these facets is not uniform even in the same eye, for sometimes those above or those in the centre are the larger; e. g. *Libellula*, *Lagria*, *Tabanus*. In general each corneule is thicker than it is broad, and thicker at its middle than at its circumference; a layer of pigment here insinuates itself into the interspaces between the corneules. In bees and flies fine hairs project from these interspaces, which must defend the eye or warn the insect against the approach of foreign bodies. Each division of the compound eye has its lens, which combines the characters of both crystalline and vitreous humours: it is always of a more or less elongated conical form, having its base applied to the corneule, and its apex to the optic nerve. The base is not immediately in contact with the cornea, but is separated by a minute aqueous chamber into which a process of the pigmental membrane penetrates, leaving a small pupil opposite the middle of the base of the lens. The pigment is continued along the crystalline vitreous cone to its apex, forming a sheath around it, and enveloping also the adhering filament of the optic nerve; at once separating and connecting together the component ocelli of the compound eye. Fine tracheal ramifications have been traced upon the pigment, which displays very various, and often brilliant or metallic, hues in its outer layer.

The larvæ of the *Coleoptera*, *Lepidoptera*, *Neuroptera*, some *Hymenoptera*, and *Diptera*, have merely simple eyes. Two or three of the larval ocelli are retained, with the superadded compound eyes, in most of the winged orders save *Coleoptera*, in which only compound eyes are present in the perfect state.

The high degree in which the power of discerning distant objects is enjoyed by the flying insects corresponds with their great power of traversing space. The few exceptional cases of blind insects are all apterous, and often peculiar to the female sex, as in the glow-worm, cochineal insect, and parasitic *Stylops*.

LECTURE XVII.

INSECTA.

extraordinary powers of locomotion possessed by insects, the
y of elements which they can traverse, their aptitude to gain
to every situation where organised matter may be obtained,
us to expect that they should manifest all the modifications
digestive system which may be required for the assimilation
different kinds and conditions of the solids and fluids of plants
nimals.

e insect preys upon another; pursues and attacks, like the
n, on the wing; but, with better mastery over the air-element,
n tear to pieces and devour its prey without alighting: another
k sedentary and inactive, imbibes the juices of a plant: a third
way into the hard wood: a fourth burrows in the earth for
worms.

traverse the surface of the earth with a succession of steps
vift for definition; some by leaps so extraordinary, as to have
d the powers of the dynamical calculator from the earliest
us. The waters, also, have their insect population; some swiftly cleaving the clear element, some gyrating on the surface, whilst others creep along the bottom. Nor are the activities of the aquatic insect confined to that lower sphere. Nepa and Dytiscus possess organs of natation, of reptation, of burrowing, and of flight. Like Milton's fiend, each is qualified for different elements, and

> "Through strait, rough, dense, or rare,
> With head, hands, wings, or feet, pursues its way,
> And swims, or sinks, or wades, or creeps, or flies."

With such diversified powers of attaining food are associated, in Insects, as varied structures for imbibing, seizing, masticating, and digesting nutritious substances. The patience of the anatomist is taxed to the utmost to unfold these delicate complexities; but his admiration is chiefly excited by the discovery that they are clearly referable to a common type.

The most marked modifications of the digestive organs relate rather to the physical condition than the chemical constitution of the food; depend more upon its being solid or fluid, than upon its being of a vegetable or animal nature. Some entomologists have separated all the insects which suck the juices of plants and animals from those which operate upon the solids, and have made the *Haustellata* and *Mandibulata* the primary divisions of the class.

The composite parts of the proboscis or siphon are however fundamentally the same as those that form the strongest or most formidable apparatus for mastication; but as they are most conspicuous and most uniformly developed for the latter office, I shall commence the demonstration of those complex parts of the mouth,—the trophi or cibarial instruments,—as they exist in a Mandibulate insect. (*fig.* 148.)

Man has two jaws only, and no Vertebrate animal has more; they work up and down, or in the direction of the axis of the body. Insects have also their upper and lower jaws—horny edentulous plates, serving in many for little else than to close the mouth, and hence called lips; the upper one (*fig.* 148, *a*) is the "labrum," the lower one (*d*) the "labium:" but they have likewise four more complex jaws, acting upon each other in pairs, from side to side, or transversely to the axis of the body. The upper pair of jaws (*b*) are called the "mandibles," the lower pair (*c*) the "maxillæ."* The three lower instruments, viz. the two maxillæ and the labium, are provided with the jointed instruments of sensation, called "palpi;" the maxillæ, in some insects, supporting each a pair of these appendages, which, besides their sensitive and selective offices, serve also to seize and hold steady the alimentary substances whilst these are divided by the mandibles and maxillæ, and represent, in fact, a third pair of lateral jaws. The lower lip has a basal joint (*mentum*), supporting a more flexible part (*ligula*, or labium proper), near to the base of which the palpi are articulated. The upper, or inner integument of the ligula, is usually developed into a kind of tongue, which is a distinct part (*lingua*) in the locusts and Libellulæ. The labrum, or upper lip, is generally a simple transverse flattened plate.

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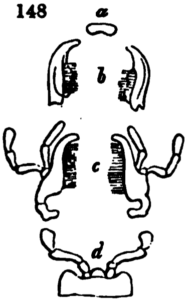

Trophi of a Mandibulate insect.

The mandibles are subject to most variety in relation to the habits and kind of food of the insect. In texture they vary from the hardest chitine to soft membrane. In the predatory tiger-beetles they terminate in sharp hooked points, like canine teeth, and are hard enough to pierce the firm integument of other insects. In the dragon-fly the inner margin of the mandibles is armed with three or four sharp laniariform processes. In some insects the upper dentations of the mandibles have a trenchant edge, like canine teeth; while the lower ones are broad and framed for bruising, like molar teeth, as in the cockchaffer or the locust. The maxillæ usually correspond with the mandibles in their general characters; but the teeth, which may be developed from their inner edge, are more uniform and delicate: their terminal piercing hook in the tiger-beetles is moveable. The maxillæ are often clothed with short hairs.

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* In vertebrate anatomy the upper or anterior jaw is called *maxilla*, the lower or hinder jaw *mandibula*. It had been well if the analogy had governed the entomological nomenclature.

The mandibles of the bee-tribe are simple, but strong and trenchant; they are most important instruments in the economy of the different species, and are modified accordingly. They model the waxen cells in the honey-bee, and form the nest in the wild-bees. In *Anthophora retusa*, the species whose trophi are figured in 149, the mandibles (*f*) are notched at the apex. The maxillæ (*g*) and labium are lengthened out to form the proboscis, but especially the labial palpi (*k*) and the lingual appendage or ligula (*), which has also two feelers, called "paraglossæ" (**), developed from its base, and has its upper surface and sides beset with hairs. In the under view of the honey-sucking and pollen-sweeping apparatus of the bee, added to *fig.* 149, *m* is the *submentum*, 1 the *cardo* of the maxilla, 2 the *stipes*, *g* the *lacinia* or blade of the maxilla, *h* the maxillary palp,

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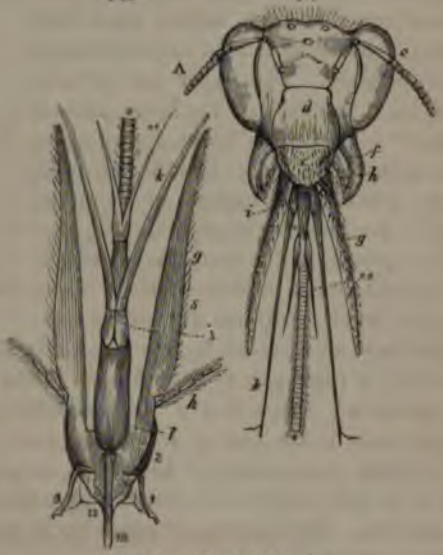

Mouth and head of a wild bee.

l the *mentum*, *i* the *labium*, *k* the labial palp, * the *lingua* or *ligula*, ** the *paraglossæ*. This definition and nomenclature of the bee's trophi are indispensable for conveying the results of such comparisons as those which enabled the venerable KIRBY to enrich Entomology with so valuable an accession of knowledge as is contained in his "Monographia Apum Angliæ," a work which the young Entomologist may take as a model.

In the Hemiptera both the mandibulæ and maxillæ are alike attenuated, and prolonged into stiff needle- or lancet-shaped organs, which are protected by a sheath formed by the equally elongated labium, the upper groove of which at the same time serves to conduct the liquid food into the mouth: the maxillary and labial palpi have disappeared; the latter may have coalesced with, and transferred their properties to, the labial sheath. With such an instrument the Cicada perforates the bark of the trees on which it lives, and exhausts their sap; and with a similar modification of the trophi, the bug and flea pierce the skin and suck the juices of animals.

In the blood-thirsty *Diptera*, as the gnat and forest fly, the labrum, as well as the two lateral pairs of jaws, are prolonged into lancet-shaped organs, and are sheathed in a thickened lower lip, which is terminated by two fleshy suckers: the maxillary palpi are attached to the base of the maxillæ.

The singular spiral "antlia" of the butterfly and other Lepidoptera is formed by the elongated slender maxillæ, still characterised by the minute palpi at their base. The inner margins of the maxillæ are concave, and the edges of the channels are in close contact, or are confluent, so as to form a canal along which the juices of flowers can be pumped up into the mouth. Each maxilla is likewise hollow, and it is uncoiled or coiled by the varying tension of this canal. The labial palpi are of large size, and defend the antlia when it is retracted and coiled up. The labrum is a small triangular piece, which bends down towards the mouth, and the rudimental, conical, slightly bent mandibles are hidden by the labial palpi.

The large curved piercing jaws of the Centipede are hollow, and traversed by the duct of a poison-gland. The anterior pair of legs are modified to come in aid of the jaws in some predatory insects, notably in the *Mantis*, *Nepa*, and *Ranatra*, where they serve to seize and hold the food to the mouth.

The alimentary canal is most simple in the larvæ of insects, in which, as in worms, it usually extends, without convolutions, from one end of the body to the other; in a few larvæ, as that of the bee, it has only the anterior opening or mouth, and the opposite or anal orifice is not developed until the pupa-state. In all mature insects the alimentary tract presents the two distinct apertures: it is simplest in the carnivorous larviform Myriapods; presents more numerous and distinct constrictions and divisions in the Hexapods, and increases in complexity and length, as the food requires most preparation in order to its conversion into the animal nutrient fluid or chyle.

The œsophagus of the Centipede is long, and dilated posteriorly, where it communicates with the stomach; this is a small muscular cavity, bent upon itself, and lined by a longitudinally plicated horny membrane. The intestine is long, straight, and wide, slightly sacculated transversely; it contracts, and is longitudinally folded near its termination. In the Iulus a short and wide œsophagus expands into a shorter and wider muscular stomach. This is succeeded by a long and wide chylific stomach, with longitudinal folds, separated by a circular linear constriction, in the posterior third of the body, from the intestine: this, again, is divided by a second constriction into two equal parts, the first longitudinally folded like the stomach, the last puckered into short transverse sacculi, until within a little distance of the anus, which is protected by a pair of horny valves.

In the Polydesmus the œsophagus gradually expands into the long chylific stomach, which is separated by a short contracted pyloric tube from the intestine. This suddenly swells out to equal width with the stomach, is puckered up in its posterior half by short transverse plicæ, where it first gradually, and then suddenly, contracts to terminate at the anus.

The accessory glands of the digestive tract are slender tubes in the Myriapod as in the Hexapod tracheary Insects. In the Polydesmus and Iulus there are two such salivary glands at the sides of the œsophagus, converging anteriorly to open into the pharynx. The more compact and similarly situated poison glands, which terminate in the large perforated hooked mandibles, in the Centipede, are superadded to the simpler salivary glands of the *Chilognatha*.

Slender biliary tubes creep upon the intestinal tunics in the Centipede, and pour their secretion into the canal close to the gizzard. Excretory, probably urinary, tubes open into the terminal division of the intestine; and these are present in the Iulidæ.

The alimentary tract in Hexapod Insects is divided into pharynx, œsophagus, ingluvies or crop, gizzard, chylific stomach, small intestine, cæcum, and rectum. All these parts rarely co-exist in the same insect. The œsophagus is directly continued from the sucking apparatus in Haustellate Insects without a pharyngeal dilatation.

In the carnivorous Dragon-fly* the alimentary tract is short and straight: there is neither crop nor gizzard, the chylific stomach is long, cylindrical, and is divided from the œsophagus by a slight constriction; the short intestine which succeeds is dilated at its commencement, and plicated longitudinally as far as the contracted rectum. In other insects a duodenal and iliac tract of intestine may be distinctly recognised. In the tiger-beetle (*Cicendela*, *fig.* 150) and the carnivorous *Carabidæ*, there is a small gizzard (*b*), preceded by the usual ingluvial dilatation of the œsophagus (*a*) and followed by a long chylific stomach, the external surface of which is beset with secerning follicles (*c*). The small intestine (*e*) makes a slight bend before terminating in the dilated colon (*f*).

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* Prep. No. 589.

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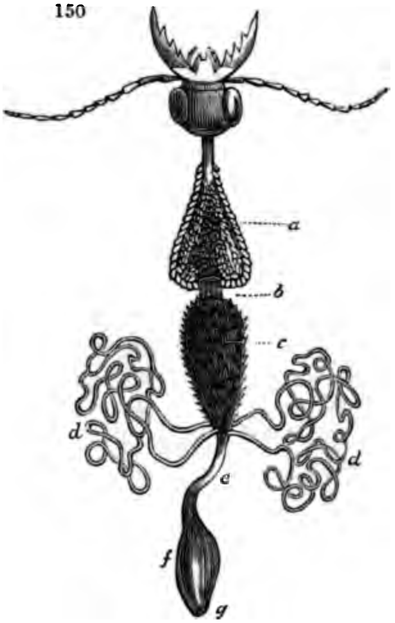

Cicendela campestris.

The alimentary canal of the browsing cockchafer is considerably longer, and is disposed in three or four coils. But in the Orthopterous vegetable-feeding insects, the canal is characterised by its superior width rather than by its length; and in them the complications requisite for animalizing the food are chiefly manifested by the gastric division. The œsophagus dilates into a wide glandular crop in the cockroaches[*] and locusts[†], and has a similar receptacle appended to it in the mole-cricket.[‡] The gizzard has a strong muscular coat and a callous epithelium, the inner surface of which is beset with projecting teeth or hooks, as in the cockroach, or with scale-like plates, as in the cricket, generally disposed in longitudinal rows. The tunics of the chylific stomach are produced at its commencement into cæcal appendages, which augment and complicate its cavity. There are two such cæca in the common and mole-crickets, four in *Locusta serrata*, six in the migratory locust, and eight in the cockroach. In the coleopterous *Buprestidæ* the stomach is prolonged into two cæcal appendages, themselves beset by smaller cæca. In the water-beetles a longish cæcum extends forward from the rectum.

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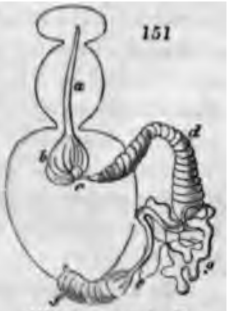
[*] Preps. Nos. 607, 608, 609.

[†] Nos. 443. 610.

[‡] No. 611.

The gizzard always coexists with the crop, but not always the crop with the gizzard, in insects. All the suctorial species have a sac, either appended to the œsophagus, or forming a preliminary [illegible]tation to the chylific stomach. It is of small size in the bug ([illegible]ex *lectularius*), and almost obsolete in other Hemiptera. In the [illegible] (fig. 151)*, the œsophagus (*a*), having traversed the thorax as a slender tube, dilates in the abdomen into the large honey-bag (*b*). The valvular funnel-sha[illegible]d orifice of the chylific stomach (*c*) pro[illegible] into the side of the ingluvial reservoir, [illegible] must be withdrawn by a special action, in [illegible] to receive any portion of the nectar for [illegible] nourishment of the bee itself: it then re[illegible] by an antiperistaltic motion, and forms a [illegible] of intussusception in the crop, converting [illegible] the convenient, closed receptacle for the [illegible]ted sweets until the bee reaches its hive; [illegible] honey, having undergone a slight [illegible] which renders it less susceptible of the acetous fermentation, [illegible]d into the waxen cell, and the crop collapses into lon[illegible]ds. The chylific stomach (*d*) is long, gradually widened [illegible] termination, and transversely plicated. The ileum (*e*) is short and slender; the colon or rectum (*f*), wide and capable of great distension. The bees on which Hunter experimented† endured a long confinement, but could not be compelled to foul their hive; as soon as liberated, they rose in the air and disburthened their overladen cloacæ.



Alimentary canal. Bee.

In the Lepidoptera (fig. 160), the ingluvies projects, like a bag, from the side of the œsophagus (*i*); and in the *Zygænæ* it is divided, as in the pigeon, into two equal parts. The chylific stomach is very small, but is sacculated, and, according to Meckel, is shaggy in the death's-head moth. The small intestine (*l*) is longer and more convoluted than in the bee; the large gut (*m*) is short and wide.

In the Diptera the crop‡, though situated upon the stomach in the abdomen, is appended by a long and slender neck to the beginning of the narrow œsophagus. The lower end of the œsophagus opens into the chylific stomach, the cardia being sometimes marked by a [illegible] ring, which is the remnant of a small bladder existing there in the larva. The small intestine is convoluted; the rectum short and dilated, and provided with two lateral conical glandular bodies.* Hunter made experiments to determine the function of the appendiculated crop. "I kept a fly," he says, "for twelve hours without food, and then gave it milk and killed it, and found no milk in the crop, but it had got through almost the whole tract of intestines: here the animal had immediate occasion for food, therefore the milk did not go into the crop. This experiment at the same time shows that every part of the intestine digests." Another time Hunter killed his flies after they had drunk their fill, and found the crop full, as well as the stomach and intestines: he suspects, therefore, that the crop serves as a reservoir, and "that when there is more food than what is immediately necessary, then it is thrown into the crop to be used in future."†

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* [illegible] 177.
† CCXLVI. p. 176.
‡ Prep. No. 596.

The result of Hunter's first experiment, and the absence of the crop in the flea and some other suctorial insects, negative the idea of Burmeister that the crop in *Hymenoptera*, *Lepidoptera*, and *Diptera* promotes the suction of food by a voluntary power of self-expansion, if even the structure of the part justified the idea; but, on the contrary, they prove it to be a receptacle of nutriment.

In the Cicadidæ the chylific stomach is of great length, intestiniform, looped, and its termination is connected, penetrating in *Cicada* beneath the muscular tunic of the first stomach, but it does not communicate therewith: the chymified fluids pass at once from its termination into the intestine.

The entire alimentary canal consists of three tunics,—an external, fine, membranous, or peritoneal layer; a compact muscular coat composed of a layer of longitudinal and a layer of circular fibres, most developed at the two extremes of the canal; and an internal mucous coat, the chitinous epithelium of which is thickest at the pharynx and the rectum. Between the muscular and epithelial coats, in the intestinal division, there is a white spongy layer of tissue, composed of aggregated cells, compared by Ramdohr to transuded chyle, and which is sometimes the seat of gastric glands.

The several divisions and convolutions of the alimentary canal are supported and attached to the adjoining parts by the air-vessels: there is no mesentery.

At least three kinds of glands add their secretions to those of the cæca and follicles of the alimentary canal. The first kind open in or near the commencement of the canal, and are regarded as salivary glands. They are classified by Professor Burmeister as follows: —

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* Prep. No. 2123.

† Physiol. Catalogue of Hunterian Collection, vol. i. p. 189.

A. Salivary vessels which open into the mouth, generally beneath the tongue, sometimes at the base of the mandibles. They take the following forms: —

1. As simple, long, undivided, twisted tubes; thus in the majority of insects, viz. all butterflies, many beetles, and flies.

2. As a narrow vessel which empties itself into one or two bladders, whence the salivary duct originates (*Nepa*, *Cimex*, *Sarcophaga*).

3. As a ramose vessel with blind branches (*Blaps*).

4. As two long cylindrical pipes, which unite into one excretory duct (*Reduvius*).

5. As four small, round bladders, each pair of which has a common duct (*Pulex*, *Lygæus*, *Cimex*).

6. As a multitude of such vesicles (*Nepa*).

7. As capitate tubes, in the free ends of which many very fine vessels empty themselves (*Tabanus*).

8. As tubes which at intervals are surrounded by spiral cæca (*Cicada*).

9. As granulated glands, which on each side unite into a salivary duct, both of which join into a single excretory duct. Müller has observed this high form of conglomerate salivary glands in *Phasma*; Treviranus in *Apis*; and Burmeister in *Locusta*, *Gryllus*, and *Termes*.

Some Entomologists ascribe a hepatic function to the closely aggregated cells forming the internal tunic of the chylific stomach, and, with more reason perhaps, to similar cells in the cæcal appendages of the stomach, when these are present. A pancreatic function is assigned to certain glandular appendages to the ilium, as *e. g.* to the two or four rows of follicles in that of some bugs (*Pentatomidæ*), and to the ramified appendages below the gastric (hepatic?) cæca in the mole-cricket (*Gryllotalpa*). There are, however, secerning organs, in the condition of long, slender, cylindrical tubes, such as Cuvier, who seems not to have been aware of the conglomerate structure of certain salivary and seminal glands, describes as the character of all the secreting organs in insects, which tubes have a degree of constancy more befitting the important excretory and accessory digestive functions of a liver, than the exceptional character of the parts above cited.

These tubes are called "Malpighian," after their discoverer.* In a few instances, as *Coccus*, *Chermes*, and *Aphis*, they are wanting: in almost all insects they are four in number, never fewer; sometimes they are six or eight in number: in a few instances, as the mole-cricket and cockroach, they are very numerous. Burmeister has generalised the observations of different anatomists on the Malpighian tubes, as follows: —

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* CCCXXII.

1. Four.
    - *a.* Free at the end; most *Diptera*, and the families *Termitina*, *Psocina*, and *Mallophaga*.
    - *b.* Anastomosing; many *Coleoptera*, *Hemiptera*, and *Diptera*.
2. Six tubes.
    - *a.* Anastomosing; many *Coleoptera*; for example, *Cerambycina* and *Chrysomelina*.
    - *b.* Free at the end; *Lepidoptera*.
3. Eight free tubes; *Neuroptera*.
4. Many tubes; *Hymenoptera*, *Orthoptera*, and the *Dictyoptera subulicornia*.

Those Malpighian tubes are longest which are fewest in number: they lie in folds by the side of the stomach and intestine, and terminate in a circle at the commencement of the small intestine. In *Lygæus apterus* they terminate in a dilatation on one side of the gut.

Uric acid has been detected* in these tubes: they have no proper epithelial lining, but are filled with cells, disposed in rows: these cells contain mucus and numerous fine granules, which impart a yellowish or greenish colour to the tubes. The granular contents pass by rupture of the discharged cells into the intestine, and may be found accumulated in the colon or cæcum: they are ultimately evacuated with the fæces. If no biliary principle be eliminated together with the uric acid from the Malpighian tubes, they are, nevertheless, by the character of their connections, relative position, and place of development from the alimentary canal, the homologues of the hepatic organs. The glands, which by the same morphological characters are more strictly urinary, are usually in the form of long and delicate tubes, but sometimes present the structure of groups of round vesicles, as in the *Carabus*, in which the common duct terminates in a small dilatation: the urinary bladder is likewise present in the water-beetles. The excretion is poured into the termination of the intestine, or evacuated contiguous to the anus.

No absorbent vessels have been detected in insects: the chyle, which is a clear or greenish fluid, with round or oval corpuscles, is supposed to transude through the tunics of the intestine into the free cavity of the abdomen: it passes, in reality, into the wide and irregular sinuses which seem to constitute the cavity of the abdomen, but which communicate with similarly ill-defined venous receptacles extending into other parts of the body and its appendages, resembling the general interspaces of the cellular tissue, and constituting the venous system, through which the blood moves in a definite and regular course to the heart. This organ (*fig.* 160, *s*) is an elongated muscular and valvular tube, situated along the middle of the back, and usually called the dorsal vessel: it is largest in the abdomen, and so diminishes anteriorly, that its continuation in the thorax may, in most insects, be regarded as the aorta. It is retained in its position by flattened triangular bands of muscular fibres. This character, its distinct transverse linear muscular fasciculi, its slight constriction at regular intervals, and the peculiar valvular loops at these constrictions, characterize the long and slender vasiform dorsal heart in the Iulus and Scolopendra, and indicate a corresponding advance with the rest of the articulate structure beyond the condition of the pulsating dorsal sanguiferous tube in the Anellids.

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* CCXLVII. A. p. 629., B. p. 213. CCXLII. p. 251.

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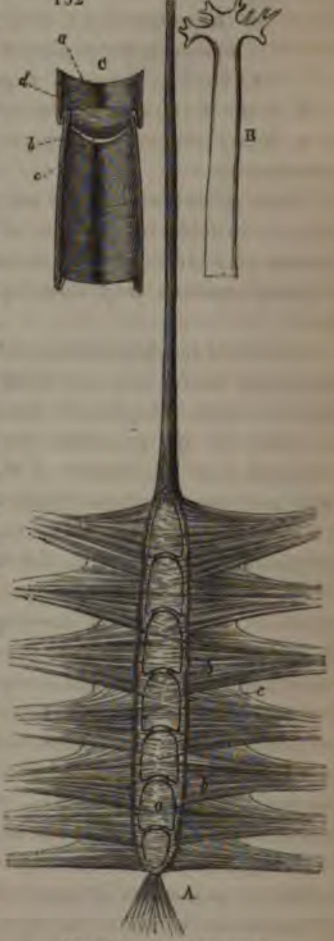

Dorsal heart of Stag-beetle.

In the perfect Hexapod Insect, the heart (*fig.* 152) has the appearance of a series of slightly conical segments (*a*), partially sheathed one upon the other: lateral apertures (C, *b*) exist at the sides of the intus-susceptions, where, in fact, valvular folds (C, *d*) of the inner tunic do project into the interior of the heart, and, with the semilunar valves (*c*), partially divide its cavity into so many separate chambers. The whole of this part of the heart is included in a saccular venous sinus (A, *c*), from which the blood passes into the interior of the heart, and, by the disposition of the valves, it is at once prevented from returning into the sinus, or passing in any other direction in the heart than towards the head, or into the next chamber in advance of that by which the fluid was admitted. The number of venous orifices varies in different insects:—in most species there are eight pairs of apertures; in the stag-beetle (*fig.* 152) there are six pairs; in the humble-bee five pairs; in the phasma there is, according to Müller, only a single pair at the posterior chamber of the heart, by which, in fact, in all Insects, the chief currents of the blood appear to enter the organ. As far as the head the blood is propelled from the heart along a tubular aorta of the usual form; but the branches from this (B) would appear soon to lose themselves in the generally diffused sinuses. In the Myriapoda, however, the blood is continued in a vessel along the dorsal aspect of the ventral nervous chord; but the traces of the true tubular vascular system are scanty and obscure.

The blood of Insects is usually a colourless fluid, sometimes greenish or straw-coloured, rarely, as in the larvæ of Chironomus, approaching to a red colour: it contains flattened oat-shaped particles, which are sometimes tuberculated.

Cuvier, misled by the anomalous diffused condition of the venous system, supposed that there was no circulation of the blood in Insects; yet the dorsal vessel was too conspicuous a structure to be overlooked. Such, however, was the authority of the great anatomist, that the nature of the heart began to be doubted, and the strangest functions to be attributed to it. Hunter, however, who was prepared to appreciate the true state of the circulating system in insects, by his discovery of the approximatively diffused and irregular structure of the veins in the Crustacea, has described in his Work on the Blood* all the leading characters of the circulation in Insects as it is recognised by Comparative Physiologists of the present day. He says, that, "As the lungs of the flying Insect are placed through the whole body, the heart is more diffused, extending through the whole length of the animal;" that "where the veins near the heart are large, there is no auricle, as in the lobster and generally in insects;" that "in the winged Insects, which have but one heart, as, also, but one circulation, there is this heart answering both purposes" (viz. the corporeal and pulmonary circulations); and again, "with respect to its use, it is, in the most simple kind of heart, to propel the blood through the body, immediately from the veins, which blood is to receive its purification in this passage, when the lungs are disposed throughout the body, as in the flying Insect." In the note at p. 221. he alludes to the animals in which the veins are entirely cellular; and expresses his idea more definitely in the following passage from his manuscript Observations on Insects:—"*Of the veins.* The veins of the Insect would appear to be simply the cellular membrane; but they are regularly formed canals, although not so distinctly cylindrical canals as in the quadruped, &c., nor branching with that regularity. They would appear to be, or to fill up, the interstices of the flakes of fat, air-cells, muscles, &c., and therefore might be called in some measure the cellular membrane of the parts."[*]

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* CCXLVIII. p. 220. *et seq.*

The chief merit of the rediscovery of the circulation of the blood in insects is due to Carus[†]; its phenomena have been witnessed in the appendages of insects by other observers, as Ehrenberg, Wagner, Burmeister, Bowerbank, and Tyrrell. Hunter counted thirty-four pulsations in a minute in the heart of a silkworm. Herhold counted from thirty to forty pulsations of the heart in a minute in a full-grown caterpillar: Suckow observed thirty per minute in a full-grown caterpillar of the pine moth, and only eighteen in its pupa state. The action of the heart is accelerated in insects, as in other animals, by muscular exertion and excitement; and Newport has counted as many as 142 pulsations in a minute, in a species of wild bee so excited.

Although the anatomist searches in vain for that profusion of arterial and venous vessels which pervade the body of most animals, the insects are not without their systems of capillary tubes, which ramify as richly over all the organs and through every tissue, and which connect together the different parts of the body. These vessels, however, carry air instead of blood: the relations between the sanguiferous and respiratory systems are reversed, and the air is distributed by a vascular system over the reservoirs of blood, instead of the blood being distributed by a capillary net-work over reservoirs of air. The aëriferous tubes in insects are called "tracheæ," having their parietes strengthened by an elastic cartilaginous filament, not indeed disposed in a series of distinct rings, but in a continuous close spiral coil. By this structure the most delicate and invisible ramifications of the air-tubes may be easily recognised under the microscope. The spiral filament is situated between the external cellular and an internal delicate epithelial lining.

The tracheæ commence either from lateral apertures, called spiracles and stigmata (*fig.* 153, *f*), or from pneumatic tubes (*i*), generally continued from the anal segment; these latter are peculiar to insects which live in water, as the Nepa and Ranatra; and usually co-exist with stigmata.

The air is conducted by the spiracles or the pneumatic tubes, or, as

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[*] Vol. ii. p. 31. Mr. Bowerbank (CCXLIX. p. 239), accurately observed that the blood was inclosed in distinct parietes, and did not flow in the common abdominal cavity, as Carus and Wagner believed.

[†] CCL.

in *Nepa*, by both, into a large longitudinal tracheal trunk (*g*), which runs near each side from one end of the body to the other; they are connected together by transverse tubes, which run across the posterior margin of each abdominal segment, and distribute an infinitude of smaller tracheal ramifications. Some of these branches dilate into air receptacles (*h*), the number and size of which, like the air-cells in birds, are in direct relation with the powers of flight. In the Nepa these reservoirs of air are confined to the thorax: in other insects, as the grasshopper, they are frequently developed also upon the transverse abdominal tracheæ: they are very capacious in the abdomen of the bee.

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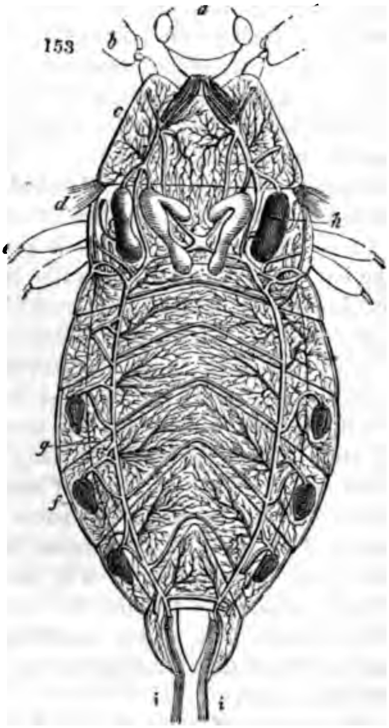

Respiratory system, Nepa.

The spiracles are narrow two-lipped orifices, situated at various points on the external surface of the body, and differing in number and size in different insects. In the Coleoptera there is a spiracle at the interspace between every two segments: the Diptera have the fewest spiracles; they are reduced to two, *e. g.*, at the extremity of the abdomen in the Œstrus larvæ. In some insects the orifice is situated upon an entire oval horny ring. In many insects, especially those that burrow, the margins of the spiracles are defended by a fringe of hairs, which prevent the entry of extraneous particles. In the larvæ of the lamellicorn beetles, the orifice is closed by a sieve-like membrane, admitting the air by the marginal pores. In the mole-cricket, the thickened margin of the spiracle is strengthened by two horny half rings, and can be closed by the action of a small sphincter muscle.

Most of the aquatic larvæ breathe by temporary gills (*branchiæ tracheales*); these consist of membranous cylinders or laminæ containing tracheal tubes. In the Phryganeæ they are filiform, united in groups of from two to five, developed from each side of the upper part of each abdominal segment, and projecting towards the back; in the *Semblidæ* plumose branchiæ are similarly situated. In *Sialidæ* the branchiæ are four or five-jointed, and are said to aid in swimming. In the larval Mayflies (*Ephemeridæ*) each of the anterior abdominal rings has a pair of branchiæ, sometimes ramified, sometimes of two kinds, one fasciculate, the other lamelliform, and performing oscillatory movements. Certain larval dragon-flies (*Agrion, Calopteryx*) have three long lamelliform branchiæ standing vertically on the hinder part of the abdomen: others (*Æsthna, Libellula*) have numerous epithelial folds, including many fine branches of tracheæ, projecting into the large rectum, the outlet of which is provided with valves to regulate the entry and escape of the water required for respiration. Rosel * has beautifully figured the branchiæ of the *Gyrinus*, or whirligig water-beetle. In a large N. American neuropterous insect (*Pteronarcys regalis*) the branchiæ, developed from the lower or sternal arcs, are persistent, and co-exist with the modified branchiæ from the upper arcs, which form the wings. They consist of eight pairs of sacs, supporting numerous long setose filaments, which form a thick tuft from the exterior of each sac; and are situated over the *stigmata* at the infero-lateral parts of the thorax and anterior segments of abdomen; each filament is traversed by a tracheal vessel. The branchi-tracheal system is more simple in the larvæ of *Tipulidæ*, in which the tracheæ that transfer the air from the water are subcutaneous. In all the modifications, the tunics of the branchial tracheæ effect that transference by actions analogous to endosmose and exosmose.†

The amount of respiration is directly as the degree of the activity of the insect; and its temperature is increased in an approximate ratio. The extraordinary development of the breathing organs demonstrate their essential relations to the energies of the muscular system; and, by a minor modification, they are made subservient to the diminution of the weight of the insect. In the Apterous insects, and especially the Myriapods, there is no trace of air vesicles, but both in the Centipede and Iulus the minute tracheæ ramify throughout the body.

The powerful and often disagreeable odour emitted by certain insects in their larval or winged state, is secreted in most by subcutaneous follicles, and excreted at particular parts of the body. The larvæ of the *Coccinellidæ* and *Tenthredinidæ* exude such fluid secretion from pores diffused over the surface of the skin. In the water-beetle (*Dytiscus*) a nauseous fluid escapes from the cephalothoracic joint; in many *Meloïdæ* and *Chrysomelidæ*, it escapes from the knee-joints; in the bug it is the product of a single pyriform gland, situated in the centre of the metathorax, and opening between the hind-legs. Other insects have anal glands, in the usual form of tubes, which, in the *Gyrinidæ*, e. g., emit a very fetid fluid. In the mole-cricket the anal glands consist of small lobular bodies, opening into a reservoir for their secretion. In the *Carabidæ* and *Staphylinidæ* the anal glands are ramified, or are vesicular, and have long excretory ducts opening into muscular reservoirs, which expel, or, in the *Brachinus*, explode the excretion, which, in the latter Bombardier-beetles, immediately becomes gaseous on its ejection.*

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* CV. Th. ii. tf. 23.

† XXIV. p. 613.

The wax of bees is formed in little scales between the hind-pair of legs. The saccharine secretion of the *Aphides*, much sought after by certain ants, exudes from teat-like processes near the vent. The pungent caustic acid (formic) of the true ants, is elaborated by a glandular apparatus in the anal region. The termites have not this excretion, and the great ant-eater refused to feed on the British species of *Formicidæ* presented to it during its captivity at the London Zoological Gardens, probably on account of their peculiar acid. The phosphorescent organs of the glow-worms (*Lampyridæ*) and fire-flies (*Elateridæ*) consist of a mass of spherical cells, filled with a finely granular substance, and surrounded by numerous tracheal ramifications. This substance, which by day-light fills, in the glow-worms, a portion of the abdominal cavity, shines through the thin integument of the ventral arcs of the last abdominal segments. In the fire-flies, the luminous substance shines through two transparent spots on the dorsal arc of the prothorax. The light brightens and dims synchronously with the acts of inspiration and expiration; it appears to be due to a slow species of combustion kept up by the oxygen of the surrounding tracheæ.†

LECTURE XVIII.

GENERATION OF INSECTS.

In the generative organs of insects, as in those of plants, Nature seems to have been prodigal in her power of producing endless varieties of forms out of one common type of organ; these varieties being subservient all the while to one common end or office. The analogy of the reproductive parts of the insect to the reproductive flower is the more striking, from the brilliant colours which the essential parts of generation assume in some species of insects. But all insects are diœcious, or of distinct sex: and there are not only "males" and "females;" but in certain families there are other kinds of individuals, which are essential to the successful propagation of the species. In the social Bees and Ants, for example, there is a third form or condition of the individual, commonly called "neuter," and sometimes labourer or nurse: these, however, are essentially female, having the female organs, but imperfectly developed and passive. The working bee, at least, exercises the function of only one part of those organs, an accessory part, which is metamorphosed into a special poison organ, but which is the homologue of the ovipositor in fertile female insects. This working bee, or "non-breeder," as Hunter called her, relieves the parturient queen of her ova, places them in the appropriate nest-cell, and feeds the larva when it is hatched: it thus acts the part of midwife as well as nurse, and is an indispensable adjunct to the multiplication of the species. There is, again, in insects, a fourth modification of the individual, in relation to the sexual function. I allude to that remarkable state of the *Aphis*, which, like the working bee, is an arrested stage of the female, constituting the larviparous individual, but which propagates by a kind of internal gemmation, without sexual concourse in her own person. She possesses, however, the female organs; but, contrariwise to the working bee, the external and accessory parts of the apparatus are wanting, whilst the more essential organs are extremely active. Thus, at the outset of our survey of the generative system and function in hexapod insects, we encounter four different kinds of individuals in relation to that function — males, fertile females, sterile females, and procreant virgins.

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* CCLI.

† XXIV. p. 632.

Certain modifications of the generative functions have served as a basis for the classification of the hexapod insects, some of which, as *e. g. Aptera*, are said to undergo no metamorphosis, and have been called "ametabola." Others, as *e. g.* the *Myriapoda*, *Hemiptera*, and *Orthoptera*, are described in entomological treatises as undergoing only a partial metamorphosis, and are called, "hemimetabola." The metamorphosis being more patent and conspicuous in the rest of the class, is admitted, said to be perfect or complete, and made the characteristic of the "metabola." The divisions so founded and defined are insufficient, however, for the generalizations of the comparative anatomist, and, by that very defect, are evidently less natural than the orders in the Linnæan system, from the characters of the wings.

The external characters which distinguish the sexes of insects are least conspicuous in the Myriapoda: the external outlets of the generative organs of the male are, however, in the Chilognatha, as in many Crustacea, situated on a segment posterior to that which is perforated by the generative organs in the female.

In the male Gally-worm (*Iulus terrestris*), the testis consists of minute cæca appended, for the most part alternately, to the sides of a long efferent tube: there are two of these on each side, which, commencing in the posterior fourth of the body, advance forwards, and unite on each side so as to form a pair of tubes; the cæcal glands continue to be developed, but in smaller number, and from one side principally of each of the common tubes. These tubes then approximate, communicate together by three or more transverse canals, and, after a slight bend or convolution, extend straight forward to the sternal arc of the seventh segment of the trunk, where they terminate by distinct orifices, on short conical protuberances, behind the seventh pair of legs.

The structure of the spermatic cæca is so similar to that of the longitudinal tubes, that the secerning function is doubtless exercised by both parts; they consist of a thick mucous coat, with an external muscular tunic; they are situated beneath, or ventrad of, the alimentary canal, and between the two large salivary vessels. In the Crustacea the testes are dorsad of the alimentary canal, and their ducts external to the glandular appendages of that canal.

The transverse anastomosing canals, between the right and left testes, remind one of the single transverse communication between the two testes in the lobster and in the crawfish; but this character is so multiplied — Newport * having found more than twenty such transverse canals in one species of Iulus — that the testes offer no unapt resemblance to a ladder. In a large species the same laborious entomotomist discovered that the semicorneous intromittent organ was defended by an uncinated valve, serving as a holder or clasper.

The contents of the testes are a clear fluid at the hinder beginning of the organs, but it becomes thick and more opaque as the outlets are approached. The change is due to the appearance of numerous sperm cells, 1·450th of a line in diameter, with a highly refracting nucleus 1·750th of a line in diameter, lying close to the cell-wall. In the progress of development the nucleus enlarges and becomes conical, the apex protruding from the surface of the cell, which finally dissolves and leaves the nucleus free. This is the spermatozoon: its breadth always exceeds its height or length. In the *Iulus fabulosus* the cell-wall becomes enlarged at the part opposite to the nucleus, and produces there a similar nuclear body; the whole thus appears like two of the spermatozoa of the *Iulus terrestris*, with their broad bases turned towards and touching each other.

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* CCII. p. 101.

In the *Chilopoda* the generative organs terminate at the anal segment of the body, not, as in the *Chilognatha*, near the fore part of the body.

In the Centipede (*Scolopendra*) the male organs are more complex, and resemble those of insects. The testes of the *Scolopendra morsitans* are seven in number, and closely packed in parallel lines; each testis is composed of two parts, fusiform, and precisely similar to each other in mutual contact, but easily separable. From each extremity of the fusiform testis arises a narrow duct, so that there are fourteen pairs of ducts arising from the fourteen secreting organs. Each of the testicular bodies is hollow internally. The ducts ultimately end in a common tube, which soon becomes enlarged and tortuous, terminating by a simple aperture near the anus. Just prior to its termination, the enlarged canal receives five accessory glands, four of which are intimately united, until unravelled, while the fifth is a simple cæcum of considerable length. The sexual outlet is situate near the anus.

There is great diversity in the structure of the male organs in the different genera of Myriapoda. In the *Scutigera*, according to Léon Dufour*, the testes are two fusiform organs, with a duct continued from each extremity; those from the upper end anastomose together, and a long and slender canal is continued from the middle of the arch, which, after a certain course, becomes disposed in a series of progressively increasing transverse folds, and finally divides into two terminal slender pyriform sacs: these are the accessory vesicles. The spermducts continued from the lower ends of the fusiform testes bend upward upon themselves, and dilate into reservoirs called "spermathecæ," similar in size and shape to the testes themselves, and each of these terminates separately upon the anal segment. The fusiform testes have many small pouches, or diverticula, produced from their outer side.

In the genus *Lithobius*†, the testes are fusiform, but free at their upper pointed ends, and they are everywhere beset with numerous subspherical or graniform secerning follicles. Three long blind tubes — accessory glands — communicate with the proper spermducts; the common opening being, as in other Chilopoda, at the terminal segment. Treviranus speaks of a small fleshy corneous penis in the *Lithobius*.

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* CCLIII. p. 97. pl. v. fig. 6.

† CCLIII. p. 87. pl. v. figs. 2, 3.

With regard to the female organs of the Myriapoda. In the *Iulus terrestris* the ovarium is a simple elongated sac, with the exterior surface nodulated by sacculi; the larger ones, of uniform size, being arranged in a double series. The ova are developed and completed in these sacculi, one in each; the germinal vesicle here is surrounded by the yolk and vitelline membrane; upon this is laid the thin layer of albumen and the corion before it passes into the common oviduct. The ova in the earlier phase of development form small projections at the interspaces of the larger and more regularly-sized ovisacs containing the more mature ova. The common elongated sac extends from the anal segment forward to near the fourth segment, where it divides, and the two vulvæ are situated on two scale-like bodies on the under surface of that apodal segment, behind the second pair of legs. A short reservoir for the male semen (*spermatheca*) communicates with each oviduct. The ovarian tube is situated beneath the alimentary canal; not above it, as in the Crustacea. If the male apertures on the seventh segment indicate, by the analogy of the Crustacea, the hinder boundaries of the thorax, we see that the more advanced position of the female apertures keeps up that analogy. Another interesting analogy presents itself in the double aperture of the generative outlets and the double intromittent or clasping organs in the male *Iulidæ*. I allude to the serpent tribe, which these Articulata resemble in their length, slenderness, and tortuous movements; for the serpents alone, amongst Vertebrata, present the double termination of the generative ducts and the double unciform claspers.

In the *Lithobius forficatus* the ovarium, a single elongated blind sac, extends from the anal segment to near the middle of the body, and is supported by the tracheal capillaries. It is beset by numerous subpedunculate unilocular bursæ, each containing a white globular ovum. These give a granular aspect to the exterior of the ovarian tube; which tube Léon Dufour suspects to be naturally divided by a median longitudinal septum.* On each side of the termination of the ovarian tube is a racemose colleterium, consisting each of two rows of granular utricules: a common duct and reservoir communicates with the oviduct.

The generative function offers so many distinctive peculiarities in the present aberrant subclass, that I shall conclude my account of it before entering upon the same subject in the typical hexapod insects.

Some important facts were early recorded relative to the metamorphoses of the Iulidæ by Degeer† and Savi‡, and their generation has been very ably and minutely worked out by Newport.§

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* CCLIII. † CCLIV. ‡ CLV § CCLII.

The *Iulus terrestris* hibernates from October to March; the female is probably impregnated prior to hybernation, for her first act after awakening from the long winter sleep is to prepare to disembarrass herself of the load of impregnated ova: the act of oviposition is generally over by the month of May. She previously excavates a special nidamental cavity in the soil, and is careful to place the eggs where no access of light, and only a certain degree of moisture, can affect them. In this process she bores the soil about an inch in depth, just wide enough to admit her own body, and then excavates a circular cavity by removing the soil, pellet by pellet, the earth being made up into a little pill by mixture with her saliva; she withdraws herself backwards from her hole, bringing up the pellet, which is held between her bent-down head and the first pair of legs: it is then passed backwards to the second pair, which transfers it to the next in succession, and so onwards, until it is removed quite out of the way. When, by the repetition of this manœuvre, the egg-chamber is completed, oviposition takes place, and the entry to the chamber is carefully closed by earth thoroughly moistened, so as to form a thick paste, which she gently presses into the entrance, and fills up nearly to a level with the surface of the soil; thus protecting the eggs from enemies that would devour them, or from the atmosphere and light which might decompose them. In this operation we may perceive that the large salivary glands have a function analogous to that of the silk glands of the *Bombyx mori*.

In the fresh-laid egg the chorion is transparent, but it becomes opaque, soon dries and shrivels when exposed to the air. The first period of development occupies about twenty-five days, when the chorion is ruptured, the egg previously augmenting in size and becoming reniform. The embryo may be recognised about the twelfth day, but presents no trace of segments or limbs; it is bent upon itself. On the thirteenth or fourteenth day there is an indication of segments on the ventral aspect. On the eighteenth day the shell bursts along the dorsal surface, and on the twenty-fifth day the embryo protrudes, by the elastic quality of its body overcoming the compression to which its growth has subjected it; but the embryo is passive and motionless, and is still connected by a reflection of an amniotic covering upon the inner surface of the membrana vitelli, which connection Newport calls the "umbilicus." There is now a head and seven segments, and the antennæ may be seen budding from the sides of the head. The internal structure of the embryo is wholly cellular, with a cavity resulting from the coalescence and liquefaction of certain central cells. On the third day after exclusion the embryo (*fig.* 154.) is passive, motionless, and still attached to the

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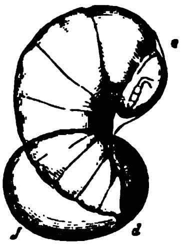

shell (*f*) by the funis-like duplicature (*d*) of the amniotic covering (*c*), and it is protected by the two halves of the egg-shell, suggestive of an analogy to the entomostracous *Cypris*. The head, antennæ, and segments of the body are better marked; transverse depressions appear on the dorsal surface of the segments, the beginning of their division into the double ones of the mature insect: but the embryo is still apodal, though rudiments, or buds of thoracic limbs, now begin to be discernible. Some of the peripheral cells become pushed into these buds of limbs, making them obtuse prior to elongation. On the ninth day the funis is ruptured, and the alimentary canal completed; but other internal parts consist of cells of different sizes. On the tenth day the dorsal vessel betrays itself by its pulsations; it drives the colourless blood to the head, which now becomes corneous; the antennæ become clubbed, and now a simple ocellus may be distinctly seen on each side. On the seventeenth day the embryo leaves the debris of its shell: it presents definite segments, articulated antennæ, and three pairs of jointed legs; it is, in short, a hexapod larva. But at the next stage of progress it quits the high road of insect development to enter a by-path of its own: new segments are formed from the penultimate or germinal segment; a remnant of the funis is converted into a rudimental anal spine; the amniotic covering and the rest of the funis are moulted.

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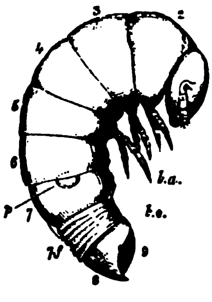

The first spontaneous movements of the embryo are to burst and slip off the amnion with the first integument; after which exertion the larva reposes, with slight occasional movements of the antennæ. We may now distinguish (*fig.* 155.) eight primary segments (1—8) besides the anal one (9). Six new segments have also been formed at the germinal space (7*f*), but these are short, and collectively are only equal to one of the original segments. The new segments are not formed by a division of the old, but by gemmation from the penultimate segment at the germinal space. The primary three pairs of legs (*b a*) are developed from the second, third, and fifth primary segments. New pairs of limbs bud out from the sixth and seventh segments. The female apertures are perforated in the fourth segment; the male outlet is established at the seventh segment, at a period when this is near the posterior end of the body of the larva. It is then marked by a patch of a darker tint than the rest of the body (*p*), and retains this character, which is of use in determining the now numerous and rapidly produced segments behind it.

The antennæ first begin to move, then the legs, and the first instinct of the locomotive larva is to shun the light. In this progression the anal segment expands, and attaches itself to the firm surface; then the body is carried forwards, the motion being propagated from segment to segment. On the twenty-sixth day the young Iulus casts off the covering in which it had hitherto been enfolded and enters the *fourth* period of development; having now seven pairs of legs and fifteen segments to its body (*fig*. 156.). The antennæ are elongated and exhibit six joints; the eye is a single ocellus, but is surrounded by pigment preparatory to subdivision; the new legs (*b*, *c*) are as long as the old ones, but not so strong; the transverse markings of the primary segments are more distinct; the patch on the seventh (*p*) is darker. The first of the new segments (8) is almost equal to the seventh primary one; the penultimate (14) and anal (15) primary segments have not much enlarged. In the progress of growth new segments are successively added at the germinal space (*g*), being always produced beneath the common integument, which is afterwards moulted. These segments are added in a certain numerical ratio, six at a time, between the antepenultimate and the penultimate segments. Movements of the larva are always observed to be fettered by the approach of the ecdysis. All the limbs superadded to the primary three pairs are bifid; and these double legs are homologous with the prolegs of caterpillars. The further course of growth is attended with a more distinct definition of the segments, and by transverse indents of the primary segments. The limbs also become more straightened. The whole period of development occupies four or five weeks, and then development is superseded by the mere act of growth.

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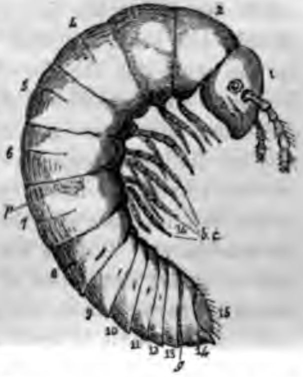

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In entering upon a review of the structure of the male organs of insects generally, we found their simplest type in the lowest organised members of the class, viz., the chilognathic myriapods. The testes and their ducts, with short and simple intromittent organs, alone existed; there were no accessory glands, no mechanical adjuncts in relation to the coitus. The sexual apertures,

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into a sperm-reservoir. The accessory prostatic glands are bent upon themselves, like a common magnet; one end of each opens into the *ductus ejaculatorius.*

In the order *Diptera* the testes always present themselves as two simple glands, either pyriform, oval, or elongated and twisted, the outer capsule of which is of a brown or yellow colour; in the *Asilus,* when this outer coat is removed, the surface of the testis is nodulated by the prominent ends of the component cæca; two slender sperm-ducts terminate in a small sperm receptacle, which also receives two long filamentary prostatic glands; a long *ductus communis* is then continued to the base of a trifid penis.*

In many of the *Lepidoptera* the testis is clothed with bright pigment, crimson in the common white butterfly (*Pontia brassicæ*), and green in the Sphinx. In most of the species the two glands approximate, and become confluent in the progress of the metamorphosis;† but in certain moths, as, *e. g.*, the *Tinea,* the originally distinct condition of the testes is retained in the imago state; the testes also remain distinct in the *Yponomeuta.*‡ In most *Lepidoptera* the vasa deferentia, or sperm-ducts, after a short course, receive two capillary prostates, and then a long and convoluted ductus ejaculatorius. What is remarkable in some butterflies (*Pontia, e. g.*), is not only the great length of the prostatic gland, but also the extreme length and winding convolutions of the common terminal duct. The structure of the intromittent organ in the Lepidoptera is such as to preclude the repetition of the act, and they consequently live in a state of compulsory monogamy. The bifid hooks on the terminal segment of the dorsal valve of the penis, whilst they serve to retain the female, prevent the entire extraction of the virile organ.

With respect to the order *Hymenoptera,* Hunter has left some good dissections of the male organs in the bee.§ The testes are of a simple oblong form; but, when we dissect away the capsule or "tunica albuginea," we expose many long cæcal tubes, which, as they uncoil and float in the liquid, give a bushy character to the gland. The sperm-duct rises from near the middle of each testis, and soon swells into a large cellular reservoir common to it, with the openings of two pyriform prostatic glands, whence a common ductus ejaculatorius is continued to the base of the intromittent organ. Newport has given a good description and figures of the male organs in a wild bee (*Athalia centifolia, fig.* 157.), in which ducts are short, and receive the secretion of two long prostatic follicles.

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* CCLVIII p. 250. CCLVIII. p. 9. taf. 1—3.

† CCXLI. tf. iv. xxxii.

‡ CCLIX. Bd. 10. f. 10.

§ X. vol. iv. pp. 34—41, Preps. Nos. 2332—2344.

In the order *Orthoptera*, we find the locusts with testes composed of numerous blind tubes, in most species enclosed in a common capsule ; and in some, *e. g.* the cockroaches (*Blatta*), the testicular follicles are collected into a common mass in the middle of the abdomen. The prostatic glands also consist of fasciculi of tubes, and remind us of the condition of the prostate in some rodentia. Their secretion is moulded into spermatophora.

The order *Coleoptera* offers the greatest diversity in the form and structure of the male organs. In *Dytiscus* each testis is a filiform tube, much longer than the abdomen, but convoluted into a round ball. In *Hydrophilus* the gland is represented by a series of short blind processes given off from one side of a common sperm-duct. In *Buprestis* a fasciculus of longer cæcal tubes radiate from the end of the sperm-duct. Sometimes the extremities of similar radiating tubes are dilated into sacculated flattened glands, as in the rose-beetle (*Cetonia*), and numerous more composite forms have been detected; all, however, are referrible to modifications of the primitive blind secerning sac. Their analogy to the sexual parts of plants has already been alluded to, and entomologists have found it requisite or advantageous to borrow the neat and descriptive terms. with which Linnæus has enriched botanical science, in order to indicate the diversified forms of the male apparatus in the subjects of their favourite class. The intromittent organ is a long horny tube ; usually retracted within the abdomen, but not capable of retraction after complete intromission, which usually terminates by rupture of the organ. Hence the *Coleoptera*, like the *Lepidoptera*, are monogamous. The terminal portion of the ejaculatory duct is continued into the penis, and, in *Carabus clathratus*, opens upon the centre of a soft glandiform termination of the intromittent organ.

Much unity of plan may be traced throughout the varied modifications of this organ in insects. In general terms, the intromittent organ may be defined as a modification of the last, or two last, segments of the abdomen. It consists of a large exterior sheath and a delicate membranous tube; the sheath commonly consists of two lateral valves. It is usually retracted out of sight. Accessory prehensile organs are developed in some insects, of which the most remarkable are those which are attached to the base of the abdomen in the male Libellula. In this remarkable insect, the sperm-ducts terminate, as usual, on the anal segment; but the vesicula seminalis is situated at the base of the abdomen. The semen is transferred thither by a strong inflection of the caudal end of the abdomen, prior

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open externally, in common with the ducts of two long,
cal appendages, upon a soft, unarmed penis. These
never contain spermatozoa; they are a simple form of
accessory prostate. The spermatozoa are found in various degrees of development in the testes; when fully developed, they form oval bundles of very fine filaments, which separate in water, at one end expanding like a bunch of flowers. The intromittent organ is not broken away *in coitu*, and the male aphis may, therefore, enjoy a frequent repetition of the act.

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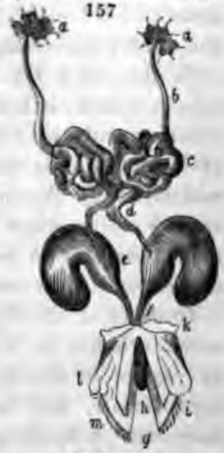

Male organs, Athalia centifolia.

The tree-bugs (*Pentatomidæ*) have two simple pyriform testes, often of a beautiful red colour: the ground-bugs (*Geocorisæ*) have seven long testicular tubes united in a fan-like manner. The testes are numerous, and similarly fasciculate, in the *Cicadidæ*. *Notonecta* has two pairs of long spiral tubular testes: *Nepa* and *Ranatra* have five flexuous testes on each side. The prostatic glands are largely developed in most Hemiptera.

Amongst the Neuroptera the testes of the May-flies (*Ephemeridæ*) and Dragon-flies (*Libellulidæ*) consist of a multitude of round follicles, disposed botryoidally around a long dilated portion of each of the sperm-ducts: the prostates are absent. In *Panorpa* the testes are simple and ovoid: in the Ant-lion (*Myrmeleo*) they consist of tufts of round follicles surrounded by a capsule; the sperm-ducts are short, and receive the secretion of two long prostatic follicles.

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The spermatozoa in all hexapod insects are filiform, and often remarkable for their extreme length; the anterior extremity is usually thickened for a considerable extent.

The sperm-cells usually contain many "spermatoa," or vesicles of development; these spermatoa are at first transparent, then granular, and lastly, the spermatozoon is developed, one in each. This makes the spermatoon change its form: it is stretched by the uncoiling of the spermatozoon, bursts and allows it to escape. Thus let free in the common sperm-cell, the spermatozoa group themselves into regular bundles. Sometimes these fasciculi resolve themselves, and the spermatozoa disperse as soon as the sperm-cell gives way; but usually a part of the sperm-cell remains as a partial sheath to the bundle, and when the spermatozoa remain in this way closely packed together, the whole bundle might be taken for a gigantic spermatozoon. The bundle is very long, and appears convoluted in a knot in *Staphylinus*, but is resolvable into its constituent spermatozoa, which become separated as they advance along the sperm-duct. But here frequently, by the addition of the prostatic secretion, they are again collected into fresh bundles, and packed up into "spermatophora." These secondary aggregates present an elegant arrangement in the *Locustinæ*, being delicately barbed like a feather, and the spermatophora, with their fertilising contents, are finally conveyed *in coitu* to the proper "vesicula seminalis," or "spermatheca," which, as in most other hexapod insects, belongs to the female.

As a general rule, the life of an insect soon ends after the great act of impregnation has been fulfilled. The change of form prior to the acquisition of the procreating power is usually extreme, and rapidly undergone; the ordinary every-day life of the insect, spent in acquiring and consuming its daily food, forms a far larger proportion of its existence, and is passed under a very different and a very inferior form; which, if in comparison to the last stage, we should regard as the more typical form of the animal, we shall not probably err. The cockchaffer passes three years as a subterranean worm, but lives hardly as many weeks in its winged state. An ordinary observer sees and knows the May-fly only in that last joyous stage of its existence, and deems its life concentrated in one winged nuptial holiday; but this so-called *Ephemera* has previously passed three hundred and more working days as an aquatic larva.

In no class of animals are the parts of generation so complex as in insects. The internal female sexual organs consist of the ovaries, the oviducts, the uterus, the spermatheca, the bursa copulatrix, the mucous glands or colleteria, the scent-glands, and the vagina; but these are not all present in all insects. The external organs are the vulva, the sting, the holders, and ovipositor; some of which are likewise peculiar to particular species.

The most constant and essential parts of generation of the female insect, viz., the ovaria, are subject to almost as many varieties as the testes in the male; their forms may be arranged into almost as many genera and species, which are very often analogous to those of the essential glands in the opposite sex. The ovaria in the Lepidoptera do not, however, coalesce into a single mass, like the testes in the male; they are either digitate or verticillate; that is to say, they consist either of a few egg-tubes suspended to the end of the oviduct, becoming attenuated as they recede from it; or they consist of numerous very long egg-tubes, proceeding from a very short oviduct, and terminating in filiform extremities, when they are usually disposed in spiral coils bending at the two sides in opposite directions, as in the *Noctua Brassicæ* (*fig.* 154, *a, a*). In the forest-fly each ovarium consists of two egg-tubes; in the flesh-fly it consists of a single tube, which is of great length, and twisted spirally. In the mantis a single series of short egg-tubes are attached to one side of a common duct. In the gnats, crickets, and locusts, the numerous egg-tubes, which are somewhat compressed, lie upon one another like scales, or the tiles upon a roof. In the Ephemera and Stratiomys the ovaries have the primitive form of simple elongated bags, in which the eggs are contained linked together by delicate filaments. In almost all cases the cæcal terminations of the ovaries are attached by a delicate thread to the thorax: the tubes themselves being connected together by a complex tracheal network.

Swammerdam* has given an accurate description, with excellent figures of the female organs of the louse, the discovery of which helped him to an excellent argument, requisite in his day, against the spontaneous generation of that parasite from the filth of the abject members of our species which it commonly infests. Five egg-tubes converge and coalesce into a single short oviduct on each side; the two unite into a common tube, with which a pair of branched or varicose accessory follicles communicate. The vulva is surrounded by four mammillary eminences: the spermatheca and bursa copulatrix are wanting.

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* CCXXXIII. p. 37, pl. 2.

The *Iulus terrestris* hibernates from October to March; the female is probably impregnated prior to hybernation, for her first act after awakening from the long winter sleep is to prepare to disembarrass herself of the load of impregnated ova: the act of oviposition is generally over by the month of May. She previously excavates a special nidamental cavity in the soil, and is careful to place the eggs where no access of light, and only a certain degree of moisture, can affect them. In this process she bores the soil about an inch in depth, just wide enough to admit her own body, and then excavates a circular cavity by removing the soil, pellet by pellet, the earth being made up into a little pill by mixture with her saliva; she withdraws herself backwards from her hole, bringing up the pellet, which is held between her bent-down head and the first pair of legs: it is then passed backwards to the second pair, which transfers it to the next in succession, and so onwards, until it is removed quite out of the way. When, by the repetition of this manœuvre, the egg-chamber is completed, oviposition takes place, and the entry to the chamber is carefully closed by earth thoroughly moistened, so as to form a thick paste, which she gently presses into the entrance, and fills up nearly to a level with the surface of the soil; thus protecting the eggs from enemies that would devour them, or from the atmosphere and light which might decompose them. In this operation we may perceive that the large salivary glands have a function analogous to that of the silk glands of the *Bombyx mori*.

In the fresh-laid egg the chorion is transparent, but it becomes opaque, soon dries and shrivels when exposed to the air. The first period of development occupies about twenty-five days, when the chorion is ruptured, the egg previously augmenting in size and becoming reniform. The embryo may be recognised about the twelfth day, but presents no trace of segments or limbs; it is bent upon itself. On the thirteenth or fourteenth day there is an indication of segments on the ventral aspect. On the eighteenth day the shell bursts along the dorsal surface, and on the twenty-fifth day the embryo protrudes, by the elastic quality of its body overcoming the compression to which its growth has subjected it; but the embryo is passive and motionless, and is still connected by a reflection of an amniotic covering upon the inner surface of the membrana vitelli, which connection Newport calls the "umbilicus." There is now a head and seven segments, and the antennæ may be seen budding from the sides of the head. The internal structure of the embryo is wholly cellular, with a cavity resulting from the coalescence and liquefaction of certain central cells. On the third day after exclusion the embryo (*fig.* 154.) is passive, motionless, and still attached to the shell (*f*) by the funis-like duplicature (*d*) of the amniotic covering (*e*), and it is protected by the two halves of the egg-shell, suggestive of an analogy to the entomostracous *Cypris*. The head, antennæ, and segments of the body are better marked; transverse depressions appear on the dorsal surface of the segments, the beginning of their division into the double ones of the mature insect: but the embryo is still apodal, though rudiments, or buds of thoracic limbs, now begin to be discernible. Some of the peripheral cells become pushed into these buds of limbs, making them obtuse prior to elongation. On the ninth day the funis is ruptured, and the alimentary canal completed; but other internal parts consist of cells of different sizes. On the tenth day the dorsal vessel betrays itself by its pulsations; it drives the colourless blood to the head, which now becomes corneous; the antennæ become clubbed, and now a simple ocellus may be distinctly seen on each side. On the seventeenth day the embryo leaves the debris of its shell: it presents definite segments, articulated antennæ, and three pairs of jointed legs; it is, in short, a hexapod larva. But at the next stage of progress it quits the high road of insect development to enter a by-path of its own: new segments are formed from the penultimate or germinal segment; a remnant of the funis is converted into a rudimental anal spine; the amniotic covering and the rest of the funis are moulted.

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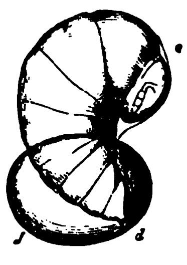

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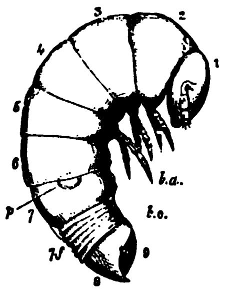

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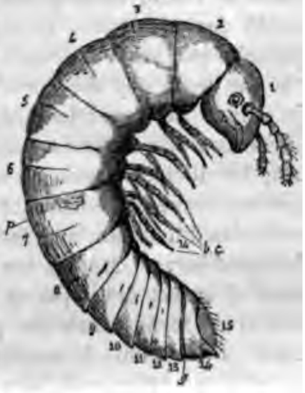

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In entering upon a review of the structure of the male organs of insects generally, we found their simplest type in the lowest organised members of the class, viz., the chilognathic myriapods. The testes and their ducts, with short and simple intromittent organs, alone existed; there were no accessory glands, no mechanical adjuncts in relation to the coitus. The sexual apertures,

such larvæ are readily distinguishable by such cocoons. Von Scheven secluded one of these virgin female larvæ of the *Psyche vestila*, and found that she laid only barren eggs.

The female larvæ of certain species of *Pysche* live quite separate from the males on peculiar feeding localities. When about to become pupæ, most of the cocoon-bearers leave those localities, and attach the mouth of the cocoon to branches of trees, to stones, or rocks. Before becoming pupæ, the grub turns itself in the cocoon, and brings its head opposite the hinder or lower free opening of the cocoon. The female pupæ manifest very little motion, but remain passive at the upper end of the sac, by which it is suspended; whilst the active male pupæ protrude their thorax from the lower opening of the cocoon shortly before emerging as the perfect moth. The almost apodal maggot-shaped females cast their pupa-skin without quitting the cocoon; they wait, in the hinder or lower free end of the cocoon, the approach of the male, which accomplishes the act without ever seeing the female of his choice.

The male Psyche has not the penis of any remarkable length, but he is able to elongate considerably the abdomen; the skin of that part is soft and extensible; he inserts the abdomen into the hinder opening of the female cocoon, and brings the external genitals into connexion with the copulatory canal of the female. After the coitus, the female, which has no ovipositor, pushes herself back again into the cast pupa-skin, and there oviposits. Also, if such a female, awaiting the male, be disturbed at the closed end of the cocoon, she returns and betakes herself wholly within her old shed pupa-skin. In the allied genus *Talæporia*, the larviform females emerge from the hinder aperture of their short cocoon, and creep, by means of their well-developed legs, to the under side of the cocoon; the generative act being performed in open day. These females have a long ovipositor, and by means of it they fill their old pupa-skin with the impregnated ova. The procreant female of *Psyche* is maggot-shaped, has no fully-developed legs, no articulate antennæ, nor distinct eyes; neither has she a trace of an ovipositor; the last abdominal segment consists only of a short fleshy cylinder, on which a short oviduct opens. The colleterium is a double pyriform glandular sac, with a short common duct. A spermatheca communicates, by a short convoluted duct, with the common vagina, which has two lateral fleshy folds, and is connected with a round bursa copulatrix, with thin and delicate walls.

Such accessories to the flabelliform ovaria and short oviducts of the *Psyche* are of themselves sufficient to show that her ova are

insight into the circumstances which rendered the successive generations from virgin Aphides possible and conceivable; and I have the greater confidence in the truth of that insight from having found it equally explanatory of the analogous phenomena of "Lucina sine concubitu" in other animals.

It is now more than a century since Bonnet, in his "Traité d'Insectologie," 8vo., 1745, first attracted the attention of physiologists and naturalists to this mode of generation in the *Aphides*, or plant-lice. And because it was the first of a large class of phenomena, till then utterly unknown and unsuspected, it was received with considerable doubt, or met by total incredulity.

The facts are briefly these: —

The impregnated ova of the Aphis are deposited, at the close of summer, in the axils of the leaves of the plant infested by the species, and the ova, retaining their latent life through the winter, are hatched by the returning warmth of spring: a wingless hexapod larva is the result of the development. This larva, if circumstances, such as warmth and food, be favourable, will produce a brood, and, indeed, a succession of broods, of eight larvæ like itself, without any connection with the male. In fact, no winged males, at this season, have appeared. If the virgin progeny be also kept from any access to the male, each will again produce a brood of the same number of aphides; and carefully prosecuted experiments have shown that this procreation from a virgin mother may continue to the seventh, the ninth, or even the eleventh generation before the spermatic virtue of the ancestral coitus has been exhausted.

When it is so exhausted, a greater proportion of cells in the germ-masses developed from the remnant retained by the last procreant larvæ are used up: individual growth and development proceed further than in the parent; some members of the last larval brood are metamorphosed into winged males, others into oviparous females; the ova are impregnated and oviposited, and thus provision is made for disseminating the individuals and for continuing the existence of the species over the severe famine-months of winter.

These phenomena, first observed, as I have said, by Bonnet, in the genus *Aphis*, were the first to which the thoughts of physiologists were bent to explain. But, being viewed in the light of an anomalous exception, and at a period when the phenomena of embryonic development were not known, the earliest steps more especially, success could not be expected.

Reamur eluded the difficulty of the fact which Bonnet had discovered, by affirming the Aphides to be androgynous. The vagina in the perfect oviparous females has appendages called spermatheca and colleterium; and Reaumur might have even appealed to the microscope in support of his idea, for he might have detected, by its aid, spermatozoa in the spermatheca. But this would not have proved the hermaphroditic structure; for the spermatheca receives the intromittent organ of the male, and retains the semen in store for the successive impregnation of the ova as they pass out; the ova at the same time being coated by the adhesive and protective matter of the colleterium. These appendages of the vagina are found in most oviparous insects; and the true male *Aphis* is as well known now as that of any other species of insect. Moreover, it is found that the viviparous virgin larvæ of the *Aphides* have not got a trace of those appendages of the vagina, which Reaumur supposed to be male organs. They were not required in her mode of generation, and are not developed. The germ-cell already exists in her, with sufficient spermatic and plastic force for its development; no semen, therefore, was required to be retained, and there is no spermatheca: the embryonic development is completed *in utero*, and no secretion for the protective covering of ova was needed. The structures, therefore, which Reaumur, under a misconception of their nature, cited in order to solve the problem of the alleged virgin procreation, are present only in that perfect form of *Aphis* where no such phenomena are manifested.

Léon Dufour,* whose extent of research and comparison of the generative organs of insects led him to a true appreciation of the nature and function of the appendages to the female organs of the oviparous *Aphides*, referred the phenomena of the generation of the larviparous *Aphides* to "spontaneous or equivocal generation." Now, if we consider what we actually learn from these words,—that the larvæ produced by the virgin Aphides are produced by "spontaneous" or equivocal generation,—it will seem to be little more than another mode of stating the fact. The condition or mode of the fact, the phenomena rendering it possible, are not explained by them; M. Léon Dufour, however, meant to record his belief in a hypothetical mode of generation, in which, as he expresses it, "the act of impregnation was in no degree concerned." Having detected the male Aphis, and well scrutinised the structure of its organs, having witnessed the coitus with the winged female, and carefully excluded the male in repeating the observations and experiments of Bonnet, M. Dufour satisfied himself, and affirmed, that impregnation had no share whatever in the phenomena of the development of the larval aphis in the body of another virgin larval aphis.

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* CCLVII.

With regard to the hypothesis of spontaneous generation, the reasons which have led me to concur with most physiologists of the present day in rejecting it were fully given in a former Course of Lectures on the subject of Generation, and every exact observation and experiment subsequently recorded serve to render that hypothesis less tenable and more gratuitous.

Professor Morren, a comparatively recent and very exact observer of the anatomy and generative economy of the *Aphides*, retaining the hypothesis of spontaneous generation as it has been applied to the Entozoa, propounded, though not without reserve, a theory that the larval aphides were developed in the body of the virgin parent, like Entozoa, "by the individualisation of a previously organised tissue." Now here also is a phrase which, when the meaning of it is analysed, does little more than express the old facts in a new way. When a larval aphis is developed, a new individual exists; in other words, it has been "individualised;" and, as nothing can come out of nothing, it must have been by the individualisation of a previously existing something. The question to be solved is, what is that something, and what has happened to that something to make its individualisation under the form of a larval aphis possible and conceivable by us according to the known analogies of other embryonic developments or individualisations? That would be the explanation of which we are in quest,—an explanation going as far as that which we are able to give, for example, of the development of an ordinarily impregnated ovum; and, by the proved analogy of the essential condition of the development in the virgin aphis with that condition in the impregnated ovum, capable of having every advance of knowledge of the operation of such essential condition applied to it.

When, however, M. Morren affirms "que la génération se fait ici, comme chez quelques Entozoaires, par l'individualisation d'un tissu précédemment organisé *," the objection immediately arises, that no one has ever seen a portion of mucous membrane, muscular fibre, or other organised tissue detach and transform itself into an entozoon: such a process is as gratuitously assumed, and as little in accordance with observed phenomena, as "spontaneous generation" in the abstract. In a former Course I objected, that "the fissiparous nucleated cells of the ovum, once metamorphosed into a tissue, can produce nothing higher, and nothing else save by their decay, which products are excreted; but the cells which retain their

primordial cells, at first round, and provided with one nucleolus, become afterwards elliptical, and generally two nucleoli can be discerned in them; afterwards two cells exist, of smaller size than the parent cell. He concludes, that this fissiparous generation of cells, which accords with that observed by Siebold and Bagge in the Ascaris, is the general mode of their multiplication:—"Hæc omnia, etsi nunquam cellulas in aliis inclusas offendi, ne ad sententiam adducunt, posteriores a prioribus gigni, ita semper binæ in unaque cellula matre oriantur.

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* Annales des Sciences Nat. t. v. 1836, p. 90.

The vitelline mass becomes elongated and vermiform, and, by further subdivision and coalescence of the peripheric stratum of the derivative germ-cells ("cambium" of Herold), a transparent integument is formed, like that in the Entozoon, first along the ventral aspect, then ascending up the sides to the dorsal aspect, which is likewise closed in by the reciprocally approximating folds which cover first the cephalic and then the caudal segments. The portion of the germ-mass remains long unchanged in the anal segment of the larva of the bee. No part of the yolk can be properly said to enter or be taken into the body of an insect. It never was out of the body: it is a "germ-yolk;" and forms the basis of the future body: there is no appended or superadded vitellus, as in the shark or bird. The division of the integument into the thirteen segments commences at the ventral aspect, which is convex, the vermiform body of the embryo being, at first, bent backwards.

In the capitate larvæ the entozoal type is quickly left by the cervical constriction, and the development of a distinct head, which commences by the formation of the part afterwards retained as the labrum. The mandibulæ and antennæ next appear behind the labrum as convex lobes; and the part of the head in the lower interspace of the mandibles forms the labium: the maxillæ then bud forth between the labium and the mandibles. The median fissure, thus surrounded by the rudimental trophi, sinks deeper into the substance of the head, and, meeting a slender anterior production of the internal vitelline sac or cavity, establishes the mouth and œsophagus. Whilst these stages are in progress, the peripheral series of included vitelline cells have undergone a series of spontaneous fissions; whereby the remaining mass becomes included within a second stratum or cambium, which, by coalescence and further metamorphoses of the cells, is transformed into the tunics of the alimentary canal, the interspace between which and the outer integument forms the abdominal cavity. A certain proportion of the vitellus, not included in the ellipsoid alimentary canal, has undergone transformations, by which the foundations of the muscular system, the ventral

The condition which renders this seemingly strange and mysterious generation of an embryo without precedent coitus possible, is the retention of a portion of the cells of the germ-mass unchanged. One sees such portion of the germ-mass taken into the semi-transparent body of the embryo Aphis, like the remnant of the yelk in the chick. I at first thought that it was about to be enclosed within the alimentary canal; but it is not so. As the embryo grows it assumes the position of the ovarium, and becomes connected with, or aids in forming the filamentary extremities of the eight oviducts. Individual development is checked and arrested at the apterous larval condition. It is plain, therefore, that the essential condition of the development of another embryo in this larva is the retention of part of the progeny of the primary impregnated germ-cell. All gemmation, external or internal, is essentially the same process; but we should learn nothing by being told that the virgin procreation of the *Aphis* was a process of internal gemmation *, unless it were shown how that was connected with the primitive mode of diffusion of the fertilising force through the germ-mass; in other words, unless the signification of the "cleavage-process" of the impregnated egg had first been appreciated, and the resemblance of its product to the basis of the bud been duly recognised.

The production of a larval Aphis may be repeated from seven to eleven times in as many successive virgin generations, without any more accession to the primary spermatic virtue of the retained cells than in the case of the successive development of polypes in the compound zoophyte, or the successive budding of the individual leaves in the equally compound plant.

At length, however, the last apterous or larval Aphis, so developed, proceeds to be "metamorphosed," as it is termed, either into a winged individual, in which only the fertilising filaments are formed, as in the case of the stamens of the plant; or, it perfects the female generative organs, and developes the ovules, as in the case of the pistil. Thus there become "male and female individuals," preceded by procreative individuals of a lower or arrested grade of organisation, analogous to the gemmiparous polypes of the zoophyte and the leaves of the plant.

The process has been described for its better intelligibility in the Aphides as one of a simple succession of single individuals, but it is much more marvellous in nature. The first-formed larva of early spring procreates not one but eight larvæ like itself in successive

broods, and each of these larvæ repeats the process; and it may be again repeated in the same geometrical ratio until a number which figures only can indicate and language almost fails to express is the result. The Aphides generated from virgin-parents, by this process of internal gemmation, are as countless as the leaves of a tree, to which they are in some respects analogous.

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* Very good observations are, nevertheless, contained in CCLXVIII.

But why, it may be asked, should there be this strange combination of viviparous generation at one season and of oviparous generation at another in the same insect? The viviparous or larviparous generation effects a multiplication of the plant-lice adequate to keep pace with the rapid growth and increase of the vegetable kingdom in the spring and summer. No sooner is the weather mild enough to effect the hatching of the ovum which may have retained its vitality through the winter, than the larva, without having to wait for the acquisition of its mature and winged form, as in other insects, forthwith begins to produce a brood, as hungry and insatiable, and as fertile as itself. The rate of increase may be conceived by the following calculation:—

The *Aphis lanigera* produces each year ten viviparous broods, and one which is oviparous, and each generation averages 100 individuals.

1st generation	1 aphis produces	
2d	100	hundred.
3d	10,000	ten thousand.
4th	1,000,000	one million.
5th	100,000,000	hundred millions.
6th	10,000,000,000	ten billions.
7th	1,000,000,000,000	one trillion.
8th	100,000,000,000,000	hundred trillions.
9th	10,000,000,000,000,000	ten quatrillions.
10th	1,000,000,000,000,000,000	one quintillion.

If the oviparous generation be added to this you will have a thirty times greater result.

It generally happens that the metamorphosis sometimes occurring after the seventh or eleventh larviparous generation takes place much earlier in the case of some of the thousands of individuals so propagated: just as a leaf-bud near the root may develope a leaf-stem, a flower and seed-capsule, with much fewer antecedent generations of leaves from buds than have preceded the formation of the flower at the summit of the plant; or just as one of the lower and earlier formed digestive polypes may push out a bud to be trans-

formed into an ovarian sac and a generative medusa. The analogy is beautifully and closely maintained throughout.

The wingless larval aphides are not very locomotive; they might have been attached to one another by continuity of integument, and each have been fixed to suck the juices from the part of the plant where it was brought forth. The stem of the rose might have been incrusted with a chain of such connected larvæ as we see the stem of a fucus incrusted with a chain of connected polypes, and only the last developed winged males and oviparous females might have been set free. The connecting medium might even have permitted a common current of nutriment contributed to by each individual to circulate through the whole compound body. But how little of anything essential to the animal would be effected by cutting through this hypothetical connecting and vascular integument and setting each individual free! If we perform this operation on the compound zoophyte, the detached polype may live and continue its gemmiparous reproduction. This is more certainly and constantly the result in detaching one of the monadiform individuals which assists in composing the seeming individual whole called "volvox globator;" and so, likewise, with the leaf-bud. And this liberation Nature has actually performed for us in the case of the Aphis, and she thereby plainly teaches us the true value or signification in morphology of the connecting links that remain to attach together the different gemmiparous individuals of the volvox, the zoophyte, and the plant.*

The phenomena of parthenogenesis have not been manifested in any articulate animal of higher organisation than insects: they cease at a lower grade of the parallel series of the molluscous invertebrata. In some lepidopterous insects, which have been supposed to have the faculty of producing fertile eggs without sexual intercourse, closer observation has shown the mistake to have arisen from the unusual circumstances under which the act of impregnation takes place. This is the case with the moths of the genus *Psyche*, which the German entomologists call "sac-träger" from the remarkable cases or sacs which the larvæ inhabit. The true state of the case has been explained by the observations of Von Scheven and Siebold.† The females of these moths never acquire wings, but develope their ova under a grade of metamorphosis very little beyond that of the larval state. The larvæ which become females fabricate an entirely different cocoon from that of the larvæ which become males, and the sexes of

* XXX.

† CCLXIII. p. 93.

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Such accessories to the flabelliform ovaria and short oviducts of the *Psyche* are of themselves sufficient to show that her ova are

destined to be impregnated. The idea that the females of this genus of moth were parthenogenetic would, however, naturally arise from observation of insulated facts in the singular series of her generative processes. Our science ever presents a picture of truth evolving itself by slow degrees from the misapprehensions of observers. An entomologist collecting the female Psyche in her unusually early arrested stage of metamorphoses, and without cognisance of the singular mode of impregnation, would at first conclude, from the analogy of other moths, that she was a virgin pupa; and, keeping her carefully insulated, would be astounded by her abundant production of fertile ova. Or, if ignorant of the peculiar place of her natural oviposition, he might well mistake the shed pupa-case, filled with fertile eggs, for an actual pupa in which such eggs had been developed.

There are many striking and beautiful manifestations of instinctive prescience in the modes of oviposition, and in the location and attachment of the ova. Observe the actions of the common white butterfly. Her food is the nectar of flowers; but, after impregnation, she flits about with a purpose quite distinct from anything connected with the act of supplying herself with nutriment: if the plant suitable to the food of the larvæ to be developed from her eggs happen to be within the range of her flight, it will soon be seen what her object is. The larvæ of most *Lepidoptera* infest, and can only be nourished properly by, the leaves of particular plants: thus, the mulberry is suitable to the silk-worm, and the cabbage to the *Pieris brassicæ;* when that commonest of our butterflies has found the cabbage, she has attained the end of her quest, and proceeds to the work of oviposition.

But a more striking illustration is found in the ichneumon-fly, which is remarkable for the great length of the anal appendages. Her food, also, is nectar; but her chief occupation in crossing over the leaves of trees and plants, after being impregnated, is to discover the larva that may be lurking in the bend of the folded leaf, preparatory to its change into the pupa-state. The ichneumon, by means of her peculiarly long, sharp, and slender ovipositor, pierces the skin of the larva, and in spite of its writhing and the ejection of an acrid fluid, she succeeds in introducing the instrument, and, by divaricating the two parts of the sheath, makes a little canal by which the ova are transmitted and lodged under the skin: she then flies off to seek another. Sometimes the female ichneumon, when she has found a larva, seems to take no notice of it; and, in that case, it has been found that another ichneumon has previously oviposited there, and, by some peculiar sense, she ascertains that

there is no room for more ova, or not food enough for such when hatched. After the ichneumon has deposited the ova, she plasters over the wound with the colleterial secretion.

In the insects of the genus *Cynips*, which are nearly allied to the ichneumons, the female has an ovipositor very similarly modified; their place for oviposition is the leaves of trees; and the ova excite an action in the cellular tissue of the leaf, which results in the formation of a warm and nutritious bed for the larvæ. The products called "nut-galls" result from such a procedure of the *Cynips Querci.* In an insect allied to *Aphis*, the *Chermes*, or *Psylla abietis*, the last act of the oviparous female, at the close of summer, is to deposit her ova in the rudimentary leaves of the fir-tree; when these leaves, instead of growing to the length of the others, become thickened, and are converted, by the irritation of the ova of the Chermes, into a series of cells of a compact structure. In the Hunterian preparation (No. 2972) a section has been removed, showing the cavities containing the larvæ. In another preparation (No. 2975) is a specimen of the article in the old Materia Medica, called "Bedeguar." It is a twig of the common wild rose, from the end of which a tuft of mossy fibres has shot out, in consequence of the irritation induced by the presence of the ova and larvæ of the *Cynips Rosæ.* Hunter has made a section of this monstrous growth, exposing several of the nidamental cavities and their small white larvæ.

In the gad-fly (*Œstrus bovis*) the ovipositor is like a telescope, terminated by boring instruments; by means of these the integument of the ox is perforated, and the egg is then deposited underneath the skin; a peculiar kind of inflammation is set up, followed by hypertrophy and condensation of the cellular tissue, and in the nidus thus produced the larvæ are developed. In the Bot-œstrus (*Gasterophilus equi*) the ova are destined to be incubated in the alimentary canal of the horse; and one might wonder how their passage could be insured into such a locality. The instinct of the female impels her to attach the ova to the hair of those parts of the body which is most readily reached by the horse's lips or tongue; the irritation of the attached ova excites the action, and so they are picked or licked off and swallowed.

Many insects deposit their eggs in the earth, and the females of such are provided with instruments for digging. In the preparations of the Locust (No. 3166 & 3168), they are seen to consist of two hard elongated valves; these, in close juxtaposition, are thrust into the earth, like the gardener's dibble; the valves are then separated by muscles, and the eggs are protruded along the interspace and deposited like seeds in the ground. The analogous part in the bee is that

which forms the sting, and this, as the defensive instrument of the nursing female, has a certain relation to the well-being of the young. Many insects not only provide the germ with the nutritive vitelline mass, or the material for the first development of the embryo, (if, indeed, the parent can be said to be concerned in that supply which is the result rather of a series of spontaneous fissions with an inherent power of assimilation of the primitive germ-cell itself,) but, in some cases, the parent having selected a fit place for the deposition of her precious burthen, continues the maternal office by placing near the ovum the kind of food which the larva will necessarily require in order to complete its growth.

Some insects, as bees and ants, feed the larvæ; supply them with the required food from time to time, as nurses satisfy the cravings of a child; but these cares seldom devolve upon the mother in the insect class: they are performed by a distinct race of individuals, of the feminine sex, but incapable themselves of exercising the procreative faculty.

The mother ear-wig, however, attends to and broods over her eggs during the whole period of larval development, turning them and removing them from place to place, according as the locality may happen to be of the required warmth or moisture.

The forms of the eggs of insects are very variable: often beautiful and regular, like the seeds of plants; sometimes very singular; always perfectly adapted to the required conditions for the development of the future insect. The eggs are cylindrical in *Bombyx everia;* conical, with tuberculate ribs, in *Pontia napi;* hemispherical in *Bombyx dumeti;* lenticular in *Noctua psi;* cup-shaped in *Orgyia antiqua;* flask-shaped in *Culex pipiens;* petiolate in *Hemerobius perla;* provided with diverging processes like ears in *Scatophaga putris,* to prevent their sinking too deep in the soft dung; provided with a special adaptation for floating in some aquatic insects; with numerous other modifications.

When impregnation has taken place, the germ-yolk becomes condensed, as in the Ascaris, receding a little from the vitelline membrane at its poles. The impregnated germ-cell propagates itself at the expense of part of the yolk, forming an oblong germ-mass, of a hyaline character, and corresponding to the ventral side of the future embryo. From the peripheral part of this, the cell-progeny extends until the whole of the vitelline mass becomes invested by a stratum of minute and nucleated cells. The first phases of development have been well observed by Herold* and Kölliker: the latter gives the following account of the process in the *Chironomus tricinctus.*† The

primordial cells, at first round, and provided with one nucleolus, become afterwards elliptical, and generally two nucleoli can be discerned in them; afterwards two cells exist, of smaller size than the parent cell. He concludes, that this fissiparous generation of cells, which accords with that observed by Siebold and Bagge in the Ascaris, is the general mode of their multiplication:—"Hæc omnia, etsi nunquam cellulas in aliis inclusas offendi, ne ad sententiam adducunt, posteriores a prioribus gigni, ita semper binæ in unaque cellula matre oriantur.

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* CCXLI.

† CCLXIV.

The vitelline mass becomes elongated and vermiform, and, by further subdivision and coalescence of the peripheric stratum of the derivative germ-cells ("cambium" of Herold), a transparent integument is formed, like that in the Entozoon, first along the ventral aspect, then ascending up the sides to the dorsal aspect, which is likewise closed in by the reciprocally approximating folds which cover first the cephalic and then the caudal segments. The portion of the germ-mass remains long unchanged in the anal segment of the larva of the bee. No part of the yolk can be properly said to enter or be taken into the body of an insect. It never was out of the body: it is a "germ-yolk;" and forms the basis of the future body: there is no appended or superadded vitellus, as in the shark or bird. The division of the integument into the thirteen segments commences at the ventral aspect, which is convex, the vermiform body of the embryo being, at first, bent backwards.

In the capitate larvæ the entozoal type is quickly left by the cervical constriction, and the development of a distinct head, which commences by the formation of the part afterwards retained as the labrum. The mandibulæ and antennæ next appear behind the labrum as convex lobes; and the part of the head in the lower interspace of the mandibles forms the labium: the maxillæ then bud forth between the labium and the mandibles. The median fissure, thus surrounded by the rudimental trophi, sinks deeper into the substance of the head, and, meeting a slender anterior production of the internal vitelline sac or cavity, establishes the mouth and œsophagus. Whilst these stages are in progress, the peripheral series of included vitelline cells have undergone a series of spontaneous fissions; whereby the remaining mass becomes included within a second stratum or cambium, which, by coalescence and further metamorphoses of the cells, is transformed into the tunics of the alimentary canal, the interspace between which and the outer integument forms the abdominal cavity. A certain proportion of the vitellus, not included in the ellipsoid alimentary canal, has undergone transformations, by which the foundations of the muscular system, the ventral

nervous chord, and the dorsal vessel, are laid. An attenuated posterior prolongation of the ellipsoid vitelline or alimentary sac forms the rectum, and opens upon the thirteenth segment.

In such a condition, but without the cephalic and trophal developments, the entozoiform larva of the flesh-fly is born or excluded from the parent: in a similar condition the larva of the bee and of the parasitic Hymenoptera quits the vermiform ovum, but without the external communication with the digestive or vitelline sac having been established at the posterior extremity.

In some Coleoptera development proceeds to the formation of the appendages of the head, as above described, and a capitate but apodal larva is excluded, as in the nut-weevil.

In other Coleoptera, as the *Donaciæ*, the ventral arcs of the second, third, and fourth segments send out bulbous rudiments of the thoracic legs, before the tergal or notal elements of the segments are completed; the abdomen is closed above, whilst the development of the extremities has proceeded to the formation of obscure joints and terminal hooks. The rudimental palpi begin to bud from the maxillæ and labium; the mandibles acquire their hard terminal hooks, and closely resemble the thoracic feet. In this state the larva is excluded.

At an earlier period the simple bulbous antennæ, mandibles, and maxillæ, indicate three cephalic segments, equal in size and distinctness to those of the thorax. The maxillary palpi, the labrum and labium, might perhaps be regarded as indicative of three other abortive segments; and if, according to the analogy of the Crustacea, the eyes are to be regarded as appendages of a proper segment, then seven cephalic segments may be reckoned, although three only can be defined by observation of the early development of the insect. The malpighian and other tubular glands result from juxtaposition in a linear series of derivative nucleated germ-cells, which coalesce by liquefaction of the parts of the cell-wall in contact with each other, the nuclei remaining longer and indicating the primitive separation of the cells. The ovarian tubes have appeared to me, in the larva of the silkworm, to retain the primitive series of nuclei of the germ-cells at their capillary beginnings; whilst coalescence of the germ-cells themselves, has taken place to form the lower part of the tube: such persistent, primitive, nuclei, or granules, seem to form the basis for the formation of the subsequent ova.

The further progress in the development of the Insect cannot be better entered upon than in the words of our celebrated entomologists, Kirby and Spence, to whom we owe the most useful and popular introduction to their delightful science. They say: —

"Were a naturalist to announce to the world the discovery o animal, which for the first five years of its life, existed in the f of a serpent; which then, penetrating into the earth, and weavin shroud of pure silk of the finest texture, contracted itself wi this covering into a body, without external mouth or limbs, and sembling, more than anything else, an Egyptian mummy; and wh lastly, after remaining in this state without food and without mo for three years longer, should, at the end of that period, burst silken cerements, struggle through its earthly covering, and s into day a winged bird, — what think you would be the sensat excited by this strange piece of intelligence? After the first dou of its truth were dispelled, what astonishment would succe Amongst the learned, what surmises! what investigations! Amon the vulgar, what eager curiosity and amazement! All would be terested in the history of such an unheard-of phenomenon; even most torpid would flock to the sight of such a prodigy." *

Now a marvel of this kind, in all its essential features, is ma fested in this country under a thousand modifications. You witness it, if you trace the life of the common beetle from the egg, watch the same course of changes in the silk-worm.

The first form under which insects appear after quitting the ovu is called the *larva*, a name devised by Linnæus, to signify, t beneath this worm-like or snake-like guise there was masked higher form. The second stage is the ***pupa*** or ***chrysalis***; and third and last stage is the ***imago***, as being the image to which all former stages tended.

Linnæus gave, also, precise terms to the different conditions of t pupa-state of the insect; and these terms have been applied by so entomologists to characterize metamorphoses generally. When t last larval skin or sheath of the pupa shows no signs whatever of t limbs or appendages of the creature within it, Linnæus called it "coarctate pupa." When the pupa-case shows, as if by a kind sculpture in relief, the character of the organs beneath it, the pu is "obtected." When the pupa case forms a special sheath for the projecting parts and appendages, the pupa is "incomplete."

In all insects the development of the embryo proceeds, with a fe secondary and unimportant modifications, in the order which has ju been described. The subsequent changes of the insect consist in t growth of all the parts, which takes place chiefly during the peri of the moult; and in the gradual acquisition of the wings, which a developed, either when the insect has reverted to the passive sta analogous to that of the ovum, as in the kinds of pupa above define or without their development being attended with any loss of activity or diminution of voracity, as, *e. g.* in the *Hemiptera* and *Orthoptera*.

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* CCLI. vol. i. Letter iii. p. 59.

The successive states of an apodal worm, of a worm with feet, and of one with feet and wings, being accompanied likewise with the acquisition and perfection of the antennal and visual organs of sense, and of the internal and external organs of generation, and often with great changes in the digestive, muscular, and nervous systems, in the development of one and the same insect, have been emphatically termed the "metamorphoses." And entomologists availing themselves of the neat definitions of the pupæ by Linnæus, have defined various kinds of metamorphoses under special heads, as the "coarctate," "obtected," "incomplete," "semi-complete," and "complete" metamorphoses.

The progress of the insect through these several stages being in many species interrupted, and active life enjoyed for a longer or shorter period under one or other of the immature forms, these have been sooner and more prominently brought nnder the notice of the naturalist, than if they had been to be sought for, as in the bird or mammal, in the early periods of the development of the minute embryo. They have consequently had assigned to them a character of singularity and exception which they do not intrinsically deserve. The different stages of development have been likewise, for the most part, studied only in the instances in which they are manifested by insects after exclusion from the egg, and thus their minor modifications and differences have attracted more attention than their essential resemblances and relations to one and the same type and course of development. As soon as the young insect breaks through the egg-shell it is, in modern Entomology, a *larva*, whatever grade of development it may have attained *in ovo:* during the period when it acquires the wings, and until their complete acquisition, it is a *pupa*.

From the importance which has been assigned, in some estimable entomological treatises and classifications, to the developmental changes of insects, and the special denominations that have been multiplied to express them, you might suppose the "complete," the "semi-complete," the "incomplete," the "obtected," and "coarctate" metamorphoses, to be different degrees, if not distinct kinds of transformations. But the insects which are said to be subject to the semi-complete and incomplete metamorphosis pass through the same kind and amount of change as those characterised by the obtected or coarctate pupa. The differences resolve themselves essentially into the place where, and the time in which, they assume and quit the vermiform state.

The Orthopterous and Hemipterous insects, characterised in entomology by a semi-complete metamorphosis, are, at one stage of their development, apodal and acephalous larvæ, like the maggot of the fly; but instead of quitting the egg in this stage, they are quickly transformed into another, in which the head and rudimental thoracic feet are developed, to the degree which characterises the hexapod larvæ of the *Carabi* and *Petalocera;* the thorax is next defined, and the parts or appendages of the head are formed, at which stage of development the young Orthopteran corresponds with the hexapod antenniferous larva of the *Meloe;* but it differs from all Coleopterous larvæ in being inactive and continuing in the egg almost until all the proportions and characters of the mature insect are acquired, save the wings.

Oddly enough that development is called "a complete metamorphosis," which is permanently arrested at the stage in which the orthopterous insect enters life, and the only hexapod insects, as the apterous *Cimex* and *Pediculus,* in which the metamorphosis is never completed, are those in which it is said to be "complete." Burmeister, however, seems to be the only entomologist who has pointed out the inaccuracy of the Fabrician definitions; but he failed to free himself from the thraldom of words when he supposed that, in the development of any insects, there was, "properly speaking, no change of form, but merely a repeated casting off of the exterior skin." *

With regard to the terms incomplete, obtected, and coarctate, they indicate, in fact, comparatively unimportant modifications of the last moulted skin of the larva of those insects which are torpid or quiescent at the period of the development of the wings. In the bee and beetle, and all *Hymenoptera* and *Coleoptera,* the legs, wings, and antennæ bud out and carry with them processes of the last larval integument, which thus forms in the pupa special sheaths for each growing organ of sense or locomotion in the perfect insect, and which organs are therefore comparatively free, although the pupa be quiescent. Lamark called such pupæ "Mumiæ."

In the obtected *Lepidoptera* the growing wings, antlia, antennæ, and thoracic legs are only partially covered by the pupal integument, being lodged in recesses on its inner surface, which make corresponding projections on its exterior, where their form and position may thus be recognised.

In the coarctate metamorphosis of the *Diptera,* the larva sheds its last skin before the growing legs and wings have impressed their forms upon it, and the exuvium constitutes an egg-shaped horny case, upon which there is not the least indication of the parts of the perfect insect.

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* CCLXV.

Under whatever form the insect be excluded from the egg, if we trace its development further back, we shall find that the tendency of the mysterious multiplication, coalescence, arrangement, and transformation of the hyaline nucleus and germ-cells is vermiform. In all insects the embryo first manifests itself as an apodal smooth Entozoon; next as an Annellide of thirteen rings: in all insects the first segment is quickly modified, and the mouth established; and in this state the larva is excluded in some insects, as the bee and fly, without any appendages being developed; and in the bee before the completion of the intestinal canal.

The maggots of the order *Diptera* and *Hymenoptera* typify the Entozoa; they have no distinct scaly head, and no thoracic legs; hence they have been termed "vermilarves." Those of the *Diptera* and of the *Ichneumonidæ* represent the parasitic worms, not only in structure, but in habits; the larvæ of the *Gastorophili* called "bots," pass that stage of their existence in the alimentary canal of higher animals. The larvæ of the *Anthorugia canicularis* may be, in like manner, considered as entozoa of the human subject. There is a breeze-fly (*Œstrus hominis*), which deposits its egg beneath the integument of the living body, and its larva there grows and flourishes like the Filaria in the cellular tissue. The larva of a species of *Cuterebra* occasionally finds its way into the human frontal sinus. Other vermilarves, as those of *Œstrus Bovis* and *Œst. Tarandi*, are developed beneath the integument or in the nasal sinuses of the Ruminants indicated by their specific names. I know not to what other modes of animal life than that of the parasitic Entozoa we can compare the habits of the voracious maggots of the flesh-fly, the essential condition of whose existence is the putrid flesh of higher organised beings. Here, however, the development of helminthoid larva has been beneficially ordained in order to neutralise the noxious effects of the otherwise inevitable processes by which dead animal matter reverts to its primitive elements. Insignificant, indeed, do these larvæ seem to be in the scale of nature, yet Linnæus used no exaggeration when he averred that three flesh-flies would devour the carcase of a horse as quickly as would a lion. The assimilative power is so great in the meat-maggot, that it will increase its own weight two hundred times in twenty-four hours.

But the developmental energies are not exhausted by the rapid growth of the larva; some remain to be exercised in the formation of the new and peculiar organs which entirely change the form and properties of the creature. For this exercise they usually require

broods, and each of these larvæ repeats the process; and it may be again repeated in the same geometrical ratio until a number which figures only can indicate and language almost fails to express is the result. The Aphides generated from virgin-parents, by this process of internal gemmation, are as countless as the leaves of a tree, to which they are in some respects analogous.

But why, it may be asked, should there be this strange combination of viviparous generation at one season and of oviparous generation at another in the same insect? The viviparous or larviparous generation effects a multiplication of the plant-lice adequate to keep pace with the rapid growth and increase of the vegetable kingdom in the spring and summer. No sooner is the weather mild enough to effect the hatching of the ovum which may have retained its vitality through the winter, than the larva, without having to wait for the acquisition of its mature and winged form, as in other insects, forthwith begins to produce a brood, as hungry and insatiable, and as fertile as itself. The rate of increase may be conceived by the following calculation:—

The *Aphis lanigera* produces each year ten viviparous broods, and one which is oviparous, and each generation averages 100 individuals.

1st generation	1 aphis produces	
2d	100	hundred.
3d	10,000	ten thousand.
4th	1,000,000	one million.
5th	100,000,000	hundred millions.
6th	10,000,000,000	ten billions.
7th	1,000,000,000,000	one trillion.
8th	100,000,000,000,000	hundred trillions.
9th	10,000,000,000,000,000	ten quatrillions.
10th	1,000,000,000,000,000,000	one quintillion.

If the oviparous generation be added to this you will have a thirty times greater result.

It generally happens that the metamorphosis sometimes occurring after the seventh or eleventh larviparous generation takes place much earlier in the case of some of the thousands of individuals so propagated: just as a leaf-bud near the root may develope a leaf-stem, a flower and seed-capsule, with much fewer antecedent generations of leaves from buds than have preceded the formation of the flower at the summit of the plant; or just as one of the lower and earlier formed digestive polypes may push out a bud to be trans-

formed into an ovarian sac and a generative medusa. The analogy is beautifully and closely maintained throughout.

The wingless larval aphides are not very locomotive; they might have been attached to one another by continuity of integument, and each have been fixed to suck the juices from the part of the plant where it was brought forth. The stem of the rose might have been incrusted with a chain of such connected larvæ as we see the stem of a fucus incrusted with a chain of connected polypes, and only the last developed winged males and oviparous females might have been set free. The connecting medium might even have permitted a common current of nutriment contributed to by each individual to circulate through the whole compound body. But how little of anything essential to the animal would be effected by cutting through this hypothetical connecting and vascular integument and setting each individual free! If we perform this operation on the compound zoophyte, the detached polype may live and continue its gemmiparous reproduction. This is more certainly and constantly the result in detaching one of the monadiform individuals which assists in composing the seeming individual whole called "volvox globator;" and so, likewise, with the leaf-bud. And this liberation Nature has actually performed for us in the case of the Aphis, and she thereby plainly teaches us the true value or signification in morphology of the connecting links that remain to attach together the different gemmiparous individuals of the volvox, the zoophyte, and the plant.*

The phenomena of parthenogenesis have not been manifested in any articulate animal of higher organisation than insects: they cease at a lower grade of the parallel series of the molluscous invertebrata. In some lepidopterous insects, which have been supposed to have the faculty of producing fertile eggs without sexual intercourse, closer observation has shown the mistake to have arisen from the unusual circumstances under which the act of impregnation takes place. This is the case with the moths of the genus *Psyche*, which the German entomologists call "sac-träger" from the remarkable cases or sacs which the larvæ inhabit. The true state of the case has been explained by the observations of Von Scheven and Siebold.† The females of these moths never acquire wings, but develope their ova under a grade of metamorphosis very little beyond that of the larval state. The larvæ which become females fabricate an entirely different cocoon from that of the larvæ which become males, and the sexes of

such larvæ are readily distinguishable by such cocoons. Von Scheven secluded one of these virgin female larvæ of the *Psyche vestila*, and found that she laid only barren eggs.

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* XXX.

† CCLXIII. p. 93.

The female larvæ of certain species of *Pysche* live quite separate from the males on peculiar feeding localities. When about to become pupæ, most of the cocoon-bearers leave those localities, and attach the mouth of the cocoon to branches of trees, to stones, or rocks. Before becoming pupæ, the grub turns itself in the cocoon, and brings its head opposite the hinder or lower free opening of the cocoon. The female pupæ manifest very little motion, but remain passive at the upper end of the sac, by which it is suspended; whilst the active male pupæ protrude their thorax from the lower opening of the cocoon shortly before emerging as the perfect moth. The almost apodal maggot-shaped females cast their pupa-skin without quitting the cocoon; they wait, in the hinder or lower free end of the cocoon, the approach of the male, which accomplishes the act without ever seeing the female of his choice.

The male Psyche has not the penis of any remarkable length, but he is able to elongate considerably the abdomen; the skin of that part is soft and extensible; he inserts the abdomen into the hinder opening of the female cocoon, and brings the external genitals into connexion with the copulatory canal of the female. After the coitus, the female, which has no ovipositor, pushes herself back again into the cast pupa-skin, and there oviposits. Also, if such a female, awaiting the male, be disturbed at the closed end of the cocoon, she returns and betakes herself wholly within her old shed pupa-skin. In the allied genus *Talæporia*, the larviform females emerge from the hinder aperture of their short cocoon, and creep, by means of their well-developed legs, to the under side of the cocoon; the generative act being performed in open day. These females have a long ovipositor, and by means of it they fill their old pupa-skin with the impregnated ova. The procreant female of *Psyche* is maggot-shaped, has no fully-developed legs, no articulate antennæ, nor distinct eyes; neither has she a trace of an ovipositor; the last abdominal segment consists only of a short fleshy cylinder, on which a short oviduct opens. The colleterium is a double pyriform glandular sac, with a short common duct. A spermatheca communicates, by a short convoluted duct, with the common vagina, which has two lateral fleshy folds, and is connected with a round bursa copulatrix, with thin and delicate walls.

Such accessories to the flabelliform ovaria and short oviducts of the *Psyche* are of themselves sufficient to show that her ova are

destined to be impregnated. The idea that the females of this genus of moth were parthenogenetic would, however, naturally arise from observation of insulated facts in the singular series of her generative processes. Our science ever presents a picture of truth evolving itself by slow degrees from the misapprehensions of observers. An entomologist collecting the female Psyche in her unusually early arrested stage of metamorphoses, and without cognisance of the singular mode of impregnation, would at first conclude, from the analogy of other moths, that she was a virgin pupa; and, keeping her carefully insulated, would be astounded by her abundant production of fertile ova. Or, if ignorant of the peculiar place of her natural oviposition, he might well mistake the shed pupa-case, filled with fertile eggs, for an actual pupa in which such eggs had been developed.

There are many striking and beautiful manifestations of instinctive prescience in the modes of oviposition, and in the location and attachment of the ova. Observe the actions of the common white butterfly. Her food is the nectar of flowers; but, after impregnation, she flits about with a purpose quite distinct from anything connected with the act of supplying herself with nutriment: if the plant suitable to the food of the larvæ to be developed from her eggs happen to be within the range of her flight, it will soon be seen what her object is. The larvæ of most *Lepidoptera* infest, and can only be nourished properly by, the leaves of particular plants: thus, the mulberry is suitable to the silk-worm, and the cabbage to the *Pieris brassicæ;* when that commonest of our butterflies has found the cabbage, she has attained the end of her quest, and proceeds to the work of oviposition.

But a more striking illustration is found in the ichneumon-fly, which is remarkable for the great length of the anal appendages. Her food, also, is nectar; but her chief occupation in crossing over the leaves of trees and plants, after being impregnated, is to discover the larva that may be lurking in the bend of the folded leaf, preparatory to its change into the pupa-state. The ichneumon, by means of her peculiarly long, sharp, and slender ovipositor, pierces the skin of the larva, and in spite of its writhing and the ejection of an acrid fluid, she succeeds in introducing the instrument, and, by divaricating the two parts of the sheath, makes a little canal by which the ova are transmitted and lodged under the skin: she then flies off to seek another. Sometimes the female ichneumon, when she has found a larva, seems to take no notice of it; and, in that case, it has been found that another ichneumon has previously oviposited there, and, by some peculiar sense, she ascertains that

there is no room for more ova, or not food enough for such when hatched. After the ichneumon has deposited the ova, she plasters over the wound with the colleterial secretion.

In the insects of the genus *Cynips*, which are nearly allied to the ichneumons, the female has an ovipositor very similarly modified; their place for oviposition is the leaves of trees; and the ova excite an action in the cellular tissue of the leaf, which results in the formation of a warm and nutritious bed for the larvæ. The products called "nut-galls" result from such a procedure of the *Cynips Querci*. In an insect allied to *Aphis*, the *Chermes*, or *Psylla abietis*, the last act of the oviparous female, at the close of summer, is to deposit her ova in the rudimentary leaves of the fir-tree; when these leaves, instead of growing to the length of the others, become thickened, and are converted, by the irritation of the ova of the Chermes, into a series of cells of a compact structure. In the Hunterian preparation (No. 2972) a section has been removed, showing the cavities containing the larvæ. In another preparation (No. 2975) is a specimen of the article in the old Materia Medica, called "Bedeguar." It is a twig of the common wild rose, from the end of which a tuft of mossy fibres has shot out, in consequence of the irritation induced by the presence of the ova and larvæ of the *Cynips Rosæ*. Hunter has made a section of this monstrous growth, exposing several of the nidamental cavities and their small white larvæ.

In the gad-fly (*Œstrus bovis*) the ovipositor is like a telescope, terminated by boring instruments; by means of these the integument of the ox is perforated, and the egg is then deposited underneath the skin; a peculiar kind of inflammation is set up, followed by hypertrophy and condensation of the cellular tissue, and in the nidus thus produced the larvæ are developed. In the Bot-œstrus (*Gasterophilus equi*) the ova are destined to be incubated in the alimentary canal of the horse; and one might wonder how their passage could be insured into such a locality. The instinct of the female impels her to attach the ova to the hair of those parts of the body which is most readily reached by the horse's lips or tongue; the irritation of the attached ova excites the action, and so they are picked or licked off and swallowed.

Many insects deposit their eggs in the earth, and the females of such are provided with instruments for digging. In the preparations of the Locust (No. 3166 & 3168), they are seen to consist of two hard elongated valves; these, in close juxtaposition, are thrust into the earth, like the gardener's dibble; the valves are then separated by muscles, and the eggs are protruded along the interspace and deposited like seeds in the ground. The analogous part in the bee is that

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When impregnation has taken place, the germ-yolk becomes condensed, as in the Ascaris, receding a little from the vitelline membrane at its poles. The impregnated germ-cell propagates itself at the expense of part of the yolk, forming an oblong germ-mass, of a hyaline character, and corresponding to the ventral side of the future embryo. From the peripheral part of this, the cell-progeny extends until the whole of the vitelline mass becomes invested by a stratum of minute and nucleated cells. The first phases of development have been well observed by Herold* and Kölliker: the latter gives the following account of the process in the *Chironomus tricinctus.*† The

primordial cells, at first round, and provided with one nucleolus, become afterwards elliptical, and generally two nucleoli can be discerned in them; afterwards two cells exist, of smaller size than the parent cell. He concludes, that this fissiparous generation of cells, which accords with that observed by Siebold and Bagge in the Ascaris, is the general mode of their multiplication:—"Hæc omnia, etsi nunquam cellulas in aliis inclusas offendi, ne ad sententiam adducunt, posteriores a prioribus gigni, ita semper binæ in unaque cellula matre oriantur.

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* CCXLI.

† CCLXIV.

The vitelline mass becomes elongated and vermiform, and, by further subdivision and coalescence of the peripheric stratum of the derivative germ-cells ("cambium" of Herold), a transparent integument is formed, like that in the Entozoon, first along the ventral aspect, then ascending up the sides to the dorsal aspect, which is likewise closed in by the reciprocally approximating folds which cover first the cephalic and then the caudal segments. The portion of the germ-mass remains long unchanged in the anal segment of the larva of the bee. No part of the yolk can be properly said to enter or be taken into the body of an insect. It never was out of the body: it is a "germ-yolk;" and forms the basis of the future body: there is no appended or superadded vitellus, as in the shark or bird. The division of the integument into the thirteen segments commences at the ventral aspect, which is convex, the vermiform body of the embryo being, at first, bent backwards.

In the capitate larvæ the entozoal type is quickly left by the cervical constriction, and the development of a distinct head, which commences by the formation of the part afterwards retained as the labrum. The mandibulæ and antennæ next appear behind the labrum as convex lobes; and the part of the head in the lower interspace of the mandibles forms the labium: the maxillæ then bud forth between the labium and the mandibles. The median fissure, thus surrounded by the rudimental trophi, sinks deeper into the substance of the head, and, meeting a slender anterior production of the internal vitelline sac or cavity, establishes the mouth and œsophagus. Whilst these stages are in progress, the peripheral series of included vitelline cells have undergone a series of spontaneous fissions; whereby the remaining mass becomes included within a second stratum or cambium, which, by coalescence and further metamorphoses of the cells, is transformed into the tunics of the alimentary canal, the interspace between which and the outer integument forms the abdominal cavity. A certain proportion of the vitellus, not included in the ellipsoid alimentary canal, has undergone transformations, by which the foundations of the muscular system, the ventral

nervous chord, and the dorsal vessel, are laid. An attenuated posterior prolongation of the ellipsoid vitelline or alimentary sac forms the rectum, and opens upon the thirteenth segment.

In such a condition, but without the cephalic and trophal developments, the entozoiform larva of the flesh-fly is born or excluded from the parent: in a similar condition the larva of the bee and of the parasitic Hymenoptera quits the vermiform ovum, but without the external communication with the digestive or vitelline sac having been established at the posterior extremity.

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At an earlier period the simple bulbous antennæ, mandibles, and maxillæ, indicate three cephalic segments, equal in size and distinctness to those of the thorax. The maxillary palpi, the labrum and labium, might perhaps be regarded as indicative of three other abortive segments; and if, according to the analogy of the Crustacea, the eyes are to be regarded as appendages of a proper segment, then seven cephalic segments may be reckoned, although three only can be defined by observation of the early development of the insect. The malpighian and other tubular glands result from juxtaposition in a linear series of derivative nucleated germ-cells, which coalesce by liquefaction of the parts of the cell-wall in contact with each other, the nuclei remaining longer and indicating the primitive separation of the cells. The ovarian tubes have appeared to me, in the larva of the silkworm, to retain the primitive series of nuclei of the germ-cells at their capillary beginnings; whilst coalescence of the germ-cells themselves, has taken place to form the lower part of the tube: such persistent, primitive, nuclei, or granules, seem to form the basis for the formation of the subsequent ova.

The further progress in the development of the Insect cannot be better entered upon than in the words of our celebrated entomologists, Kirby and Spence, to whom we owe the most useful and popular introduction to their delightful science. They say: —

"Were a naturalist to announce to the world the discovery of a animal, which for the first five years of its life, existed in the for of a serpent; which then, penetrating into the earth, and weaving shroud of pure silk of the finest texture, contracted itself withi this covering into a body, without external mouth or limbs, and resembling, more than anything else, an Egyptian mummy; and whic lastly, after remaining in this state without food and without motio for three years longer, should, at the end of that period, burst it silken cerements, struggle through its earthly covering, and star into day a winged bird, — what think you would be the sensatio excited by this strange piece of intelligence? After the first doubt of its truth were dispelled, what astonishment would succeed Amongst the learned, what surmises! what investigations! Amongs the vulgar, what eager curiosity and amazement! All would be interested in the history of such an unheard-of phenomenon; even th most torpid would flock to the sight of such a prodigy." *

Now a marvel of this kind, in all its essential features, is manifested in this country under a thousand modifications. You wil witness it, if you trace the life of the common beetle from the egg, o watch the same course of changes in the silk-worm.

The first form under which insects appear after quitting the ovum is called the *larva*, a name devised by Linnæus, to signify, tha beneath this worm-like or snake-like guise there was masked higher form. The second stage is the *pupa* or *chrysalis;* and th third and last stage is the *imago,* as being the image to which all th former stages tended.

Linnæus gave, also, precise terms to the different conditions of th pupa-state of the insect; and these terms have been applied by som entomologists to characterize metamorphoses generally. When th last larval skin or sheath of the pupa shows no signs whatever of th limbs or appendages of the creature within it, Linnæus called it "coarctate pupa." When the pupa-case shows, as if by a kind o sculpture in relief, the character of the organs beneath it, the pup is "obtected." When the pupa case forms a special sheath for al the projecting parts and appendages, the pupa is "incomplete."

In all insects the development of the embryo proceeds, with a few secondary and unimportant modifications, in the order which has jus been described. The subsequent changes of the insect consist in th growth of all the parts, which takes place chiefly during the perio of the moult; and in the gradual acquisition of the wings, which ar developed, either when the insect has reverted to the passive stat analogous to that of the ovum, as in the kinds of pupa above defined or without their development being attended with any loss of activity or diminution of voracity, as, *e. g.* in the *Hemiptera* and *Orthoptera.*

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* CCLI. vol. i. Letter iii. p. 59.

The successive states of an apodal worm, of a worm with feet, and of one with feet and wings, being accompanied likewise with the acquisition and perfection of the antennal and visual organs of sense, and of the internal and external organs of generation, and often with great changes in the digestive, muscular, and nervous systems, in the development of one and the same insect, have been emphatically termed the "metamorphoses." And entomologists availing themselves of the neat definitions of the pupæ by Linnæus, have defined various kinds of metamorphoses under special heads, as the "coarctate," "obtected," "incomplete," "semi-complete," and "complete" metamorphoses.

The progress of the insect through these several stages being in many species interrupted, and active life enjoyed for a longer or shorter period under one or other of the immature forms, these have been sooner and more prominently brought nnder the notice of the naturalist, than if they had been to be sought for, as in the bird or mammal, in the early periods of the development of the minute embryo. They have consequently had assigned to them a character of singularity and exception which they do not intrinsically deserve. The different stages of development have been likewise, for the most part, studied only in the instances in which they are manifested by insects after exclusion from the egg, and thus their minor modifications and differences have attracted more attention than their essential resemblances and relations to one and the same type and course of development. As soon as the young insect breaks through the egg-shell it is, in modern Entomology, a *larva,* whatever grade of development it may have attained *in ovo:* during the period when it acquires the wings, and until their complete acquisition, it is a *pupa.*

From the importance which has been assigned, in some estimable entomological treatises and classifications, to the developmental changes of insects, and the special denominations that have been multiplied to express them, you might suppose the "complete," the "semi-complete," the "incomplete," the "obtected," and "coarctate" metamorphoses, to be different degrees, if not distinct kinds of transformations. But the insects which are said to be subject to the semi-complete and incomplete metamorphosis pass through the same kind and amount of change as those characterised by the obtected or coarctate pupa. The differences resolve themselves essentially into the place where, and the time in which, they assume and quit the vermiform state.

broods, and each of these larvæ repeats the process; and it may be again repeated in the same geometrical ratio until a number which figures only can indicate and language almost fails to express is the result. The Aphides generated from virgin-parents, by this process of internal gemmation, are as countless as the leaves of a tree, to which they are in some respects analogous.

But why, it may be asked, should there be this strange combination of viviparous generation at one season and of oviparous generation at another in the same insect? The viviparous or larviparous generation effects a multiplication of the plant-lice adequate to keep pace with the rapid growth and increase of the vegetable kingdom in the spring and summer. No sooner is the weather mild enough to effect the hatching of the ovum which may have retained its vitality through the winter, than the larva, without having to wait for the acquisition of its mature and winged form, as in other insects, forthwith begins to produce a brood, as hungry and insatiable, and as fertile as itself. The rate of increase may be conceived by the following calculation:—

The *Aphis lanigera* produces each year ten viviparous broods, and one which is oviparous, and each generation averages 100 individuals.

1st generation	1 aphis produces	
2d	100	hundred.
3d	10,000	ten thousand.
4th	1,000,000	one million.
5th	100,000,000	hundred millions.
6th	10,000,000,000	ten billions.
7th	1,000,000,000,000	one trillion.
8th	100,000,000,000,000	hundred trillions.
9th	10,000,000,000,000,000	ten quatrillions.
10th	1,000,000,000,000,000,000	one quintillion.

If the oviparous generation be added to this you will have a thirty times greater result.

It generally happens that the metamorphosis sometimes occurring after the seventh or eleventh larviparous generation takes place much earlier in the case of some of the thousands of individuals so propagated: just as a leaf-bud near the root may develope a leaf-stem, a flower and seed-capsule, with much fewer antecedent generations of leaves from buds than have preceded the formation of the flower at the summit of the plant; or just as one of the lower and earlier formed digestive polypes may push out a bud to be trans-

formed into an ovarian sac and a generative medusa. The analogy is beautifully and closely maintained throughout.

The wingless larval aphides are not very locomotive; they might have been attached to one another by continuity of integument, and each have been fixed to suck the juices from the part of the plant where it was brought forth. The stem of the rose might have been incrusted with a chain of such connected larvæ as we see the stem of a fucus incrusted with a chain of connected polypes, and only the last developed winged males and oviparous females might have been set free. The connecting medium might even have permitted a common current of nutriment contributed to by each individual to circulate through the whole compound body. But how little of anything essential to the animal would be effected by cutting through this hypothetical connecting and vascular integument and setting each individual free! If we perform this operation on the compound zoophyte, the detached polype may live and continue its gemmiparous reproduction. This is more certainly and constantly the result in detaching one of the monadiform individuals which assists in composing the seeming individual whole called "volvox globator;" and so, likewise, with the leaf-bud. And this liberation Nature has actually performed for us in the case of the Aphis, and she thereby plainly teaches us the true value or signification in morphology of the connecting links that remain to attach together the different gemmiparous individuals of the volvox, the zoophyte, and the plant.*

The phenomena of parthenogenesis have not been manifested in any articulate animal of higher organisation than insects: they cease at a lower grade of the parallel series of the molluscous invertebrata. In some lepidopterous insects, which have been supposed to have the faculty of producing fertile eggs without sexual intercourse, closer observation has shown the mistake to have arisen from the unusual circumstances under which the act of impregnation takes place. This is the case with the moths of the genus *Psyche*, which the German entomologists call "sac-träger" from the remarkable cases or sacs which the larvæ inhabit. The true state of the case has been explained by the observations of Von Scheven and Siebold.† The females of these moths never acquire wings, but develope their ova under a grade of metamorphosis very little beyond that of the larval state. The larvæ which become females fabricate an entirely different cocoon from that of the larvæ which become males, and the sexes of

such larvæ are readily distinguishable by such cocoons. Von Scheven secluded one of these virgin female larvæ of the *Psyche vestila*, and found that she laid only barren eggs.

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* XXX.

† CCLXIII. p. 93.

The female larvæ of certain species of *Pysche* live quite separate from the males on peculiar feeding localities. When about to become pupæ, most of the cocoon-bearers leave those localities, and attach the mouth of the cocoon to branches of trees, to stones, or rocks. Before becoming pupæ, the grub turns itself in the cocoon, and brings its head opposite the hinder or lower free opening of the cocoon. The female pupæ manifest very little motion, but remain passive at the upper end of the sac, by which it is suspended; whilst the active male pupæ protrude their thorax from the lower opening of the cocoon shortly before emerging as the perfect moth. The almost apodal maggot-shaped females cast their pupa-skin without quitting the cocoon; they wait, in the hinder or lower free end of the cocoon, the approach of the male, which accomplishes the act without ever seeing the female of his choice.

The male Psyche has not the penis of any remarkable length, but he is able to elongate considerably the abdomen; the skin of that part is soft and extensible; he inserts the abdomen into the hinder opening of the female cocoon, and brings the external genitals into connexion with the copulatory canal of the female. After the coitus, the female, which has no ovipositor, pushes herself back again into the cast pupa-skin, and there oviposits. Also, if such a female, awaiting the male, be disturbed at the closed end of the cocoon, she returns and betakes herself wholly within her old shed pupa-skin. In the allied genus *Talæporia*, the larviform females emerge from the hinder aperture of their short cocoon, and creep, by means of their well-developed legs, to the under side of the cocoon; the generative act being performed in open day. These females have a long ovipositor, and by means of it they fill their old pupa-skin with the impregnated ova. The procreant female of *Psyche* is maggot-shaped, has no fully-developed legs, no articulate antennæ, nor distinct eyes; neither has she a trace of an ovipositor; the last abdominal segment consists only of a short fleshy cylinder, on which a short oviduct opens. The colleterium is a double pyriform glandular sac, with a short common duct. A spermatheca communicates, by a short convoluted duct, with the common vagina, which has two lateral fleshy folds, and is connected with a round bursa copulatrix, with thin and delicate walls.

Such accessories to the flabelliform ovaria and short oviducts of the *Psyche* are of themselves sufficient to show that her ova are

destined to be impregnated. The idea that the females of this genus of moth were parthenogenetic would, however, naturally arise from observation of insulated facts in the singular series of her generative processes. Our science ever presents a picture of truth evolving itself by slow degrees from the misapprehensions of observers. An entomologist collecting the female Psyche in her unusually early arrested stage of metamorphoses, and without cognisance of the singular mode of impregnation, would at first conclude, from the analogy of other moths, that she was a virgin pupa; and, keeping her carefully insulated, would be astounded by her abundant production of fertile ova. Or, if ignorant of the peculiar place of her natural oviposition, he might well mistake the shed pupa-case, filled with fertile eggs, for an actual pupa in which such eggs had been developed.

There are many striking and beautiful manifestations of instinctive prescience in the modes of oviposition, and in the location and attachment of the ova. Observe the actions of the common white butterfly. Her food is the nectar of flowers; but, after impregnation, she flits about with a purpose quite distinct from anything connected with the act of supplying herself with nutriment: if the plant suitable to the food of the larvæ to be developed from her eggs happen to be within the range of her flight, it will soon be seen what her object is. The larvæ of most *Lepidoptera* infest, and can only be nourished properly by, the leaves of particular plants: thus, the mulberry is suitable to the silk-worm, and the cabbage to the *Pieris brassicæ;* when that commonest of our butterflies has found the cabbage, she has attained the end of her quest, and proceeds to the work of oviposition.

But a more striking illustration is found in the ichneumon-fly, which is remarkable for the great length of the anal appendages. Her food, also, is nectar; but her chief occupation in crossing over the leaves of trees and plants, after being impregnated, is to discover the larva that may be lurking in the bend of the folded leaf, preparatory to its change into the pupa-state. The ichneumon, by means of her peculiarly long, sharp, and slender ovipositor, pierces the skin of the larva, and in spite of its writhing and the ejection of an acrid fluid, she succeeds in introducing the instrument, and, by divaricating the two parts of the sheath, makes a little canal by which the ova are transmitted and lodged under the skin: she then flies off to seek another. Sometimes the female ichneumon, when she has found a larva, seems to take no notice of it; and, in that case, it has been found that another ichneumon has previously oviposited there, and, by some peculiar sense, she ascertains that

there is no room for more ova, or not food enough for such when hatched. After the ichneumon has deposited the ova, she plasters over the wound with the colleterial secretion.

In the insects of the genus *Cynips*, which are nearly allied to the ichneumons, the female has an ovipositor very similarly modified; their place for oviposition is the leaves of trees; and the ova excite an action in the cellular tissue of the leaf, which results in the formation of a warm and nutritious bed for the larvæ. The products called "nut-galls" result from such a procedure of the *Cynips Querci*. In an insect allied to *Aphis*, the *Chermes*, or *Psylla abietis*, the last act of the oviparous female, at the close of summer, is to deposit her ova in the rudimentary leaves of the fir-tree; when these leaves, instead of growing to the length of the others, become thickened, and are converted, by the irritation of the ova of the Chermes, into a series of cells of a compact structure. In the Hunterian preparation (No. 2972) a section has been removed, showing the cavities containing the larvæ. In another preparation (No. 2975) is a specimen of the article in the old Materia Medica, called "Bedeguar." It is a twig of the common wild rose, from the end of which a tuft of mossy fibres has shot out, in consequence of the irritation induced by the presence of the ova and larvæ of the *Cynips Rosæ*. Hunter has made a section of this monstrous growth, exposing several of the nidamental cavities and their small white larvæ.

In the gad-fly (*Œstrus bovis*) the ovipositor is like a telescope, terminated by boring instruments; by means of these the integument of the ox is perforated, and the egg is then deposited underneath the skin; a peculiar kind of inflammation is set up, followed by hypertrophy and condensation of the cellular tissue, and in the nidus thus produced the larvæ are developed. In the Bot-œstrus (*Gasterophilus equi*) the ova are destined to be incubated in the alimentary canal of the horse; and one might wonder how their passage could be insured into such a locality. The instinct of the female impels her to attach the ova to the hair of those parts of the body which is most readily reached by the horse's lips or tongue; the irritation of the attached ova excites the action, and so they are picked or licked off and swallowed.

Many insects deposit their eggs in the earth, and the females of such are provided with instruments for digging. In the preparations of the Locust (No. 3166 & 3168), they are seen to consist of two hard elongated valves; these, in close juxtaposition, are thrust into the earth, like the gardener's dibble; the valves are then separated by muscles, and the eggs are protruded along the interspace and deposited like seeds in the ground. The analogous part in the bee is that

which forms the sting, and this, as the defensive instrument of the nursing female, has a certain relation to the well-being of the young. Many insects not only provide the germ with the nutritive vitelline mass, or the material for the first development of the embryo, (if, indeed, the parent can be said to be concerned in that supply which is the result rather of a series of spontaneous fissions with an inherent power of assimilation of the primitive germ-cell itself,) but, in some cases, the parent having selected a fit place for the deposition of her precious burthen, continues the maternal office by placing near the ovum the kind of food which the larva will necessarily require in order to complete its growth.

Some insects, as bees and ants, feed the larvæ; supply them with the required food from time to time, as nurses satisfy the cravings of a child; but these cares seldom devolve upon the mother in the insect class: they are performed by a distinct race of individuals, of the feminine sex, but incapable themselves of exercising the procreative faculty.

The mother ear-wig, however, attends to and broods over her eggs during the whole period of larval development, turning them and removing them from place to place, according as the locality may happen to be of the required warmth or moisture.

The forms of the eggs of insects are very variable: often beautiful and regular, like the seeds of plants; sometimes very singular; always perfectly adapted to the required conditions for the development of the future insect. The eggs are cylindrical in *Bombyx everia;* conical, with tuberculate ribs, in *Pontia napi;* hemispherical in *Bombyx dumeti;* lenticular in *Noctua psi;* cup-shaped in *Orgyia antiqua;* flask-shaped in *Culex pipiens;* petiolate in *Hemerobius perla;* provided with diverging processes like ears in *Scatophaga putris,* to prevent their sinking too deep in the soft dung; provided with a special adaptation for floating in some aquatic insects; with numerous other modifications.

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* CCXLI. † CCLXIV.

Order Neuroptera. (May-flies, Dragon-flies.)

Four wings, membranous, veined with numerous reticulate nervures. Larvæ hexapod, unlike imago; in many aquatic.

Families *Phryganidæ, Sialidæ, Hemerobidæ, Myrmeleonidæ, Termitidæ, Raphidiadæ, Panorpidæ, Mantispidæ, Ephemeridæ, Libellulidæ.*

Order Orthoptera. (Crickets, Cockroaches.)

Four wings; the first pair coriaceous, nerved; second pair folded fan-wise, longitudinally. Larvæ like imago, save in wanting wings.

Families *Forficulidæ, Psocidæ, Acrididæ, Achetidæ, Phasmidæ, Mantidæ, Blattidæ.*

Order Coleoptera. (Beetles.)

Four wings; the first pair elytra, or hard covers to the under wings, which are folded transversely when so protected. Larvæ vermiform, hexapod in most.

A. Pentamera.	Five joints in all the tarsi. Families *Cicindelidæ, Carabidæ, Hydrocanthari, Brachelytra, Buprestidæ, Elateridæ, Clavicornes, Hydrophilidæ, Lamellicornes.*
B. Heteromera.	Five joints in the four anterior tarsi, four joints in the last tarsi. Families *Blapsidæ, Tenebrionidæ, Taxicornes, Cistelidæ, Meloidæ.*
C. Tetramera.	Four distinct joints in all the tarsi. Families *Rhyncophoridæ, Curculionidæ, Xylophagi, Cerambycidæ, Chrysomelidæ, Coccinellidæ, Pselaphidæ.*

LECTURE XIX.

ARACHNIDA.

There remains one class of articulate animals to be considered in our present ascending survey of the animal kingdom, and which, therefore, you will conclude to be the highest organised of the homogangliate Invertebrata. Yet the species which are grouped together under the name *Arachnida* never acquire wings: some are parasitic, many terrestrial, and a few aquatic: there are species, however, that, notwithstanding their apterous condition, can rise and float through the air, which they effect in a manner analogous to our aëronauts, by manufacturing, and suspending themselves to, a foreign substance light enough to be buoyed up and wafted along by the atmospheric currents. The animals to which I allude, and whose

nervous chord, and the dorsal vessel, are laid. An attenuated posterior prolongation of the ellipsoid vitelline or alimentary sac forms the rectum, and opens upon the thirteenth segment.

In such a condition, but without the cephalic and trophal developments, the entozoiform larva of the flesh-fly is born or excluded from the parent: in a similar condition the larva of the bee and of the parasitic Hymenoptera quits the vermiform ovum, but without the external communication with the digestive or vitelline sac having been established at the posterior extremity.

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At an earlier period the simple bulbous antennæ, mandibles, and maxillæ, indicate three cephalic segments, equal in size and distinctness to those of the thorax. The maxillary palpi, the labrum and labium, might perhaps be regarded as indicative of three other abortive segments; and if, according to the analogy of the Crustacea, the eyes are to be regarded as appendages of a proper segment, then seven cephalic segments may be reckoned, although three only can be defined by observation of the early development of the insect. The malpighian and other tubular glands result from juxtaposition in a linear series of derivative nucleated germ-cells, which coalesce by liquefaction of the parts of the cell-wall in contact with each other, the nuclei remaining longer and indicating the primitive separation of the cells. The ovarian tubes have appeared to me, in the larva of the silkworm, to retain the primitive series of nuclei of the germ-cells at their capillary beginnings; whilst coalescence of the germ-cells themselves, has taken place to form the lower part of the tube: such persistent, primitive, nuclei, or granules, seem to form the basis for the formation of the subsequent ova.

The further progress in the development of the Insect cannot be better entered upon than in the words of our celebrated entomologists, Kirby and Spence, to whom we owe the most useful and popular introduction to their delightful science. They say: —

in the perfect oviparous females has appendages called spermatheca and colleterium; and Reaumur might have even appealed to the microscope in support of his idea, for he might have detected, by its aid, spermatozoa in the spermatheca. But this would not have proved the hermaphroditic structure; for the spermatheca receives the intromittent organ of the male, and retains the semen in store for the successive impregnation of the ova as they pass out; the ova at the same time being coated by the adhesive and protective matter of the colleterium. These appendages of the vagina are found in most oviparous insects; and the true male *Aphis* is as well known now as that of any other species of insect. Moreover, it is found that the viviparous virgin larvæ of the *Aphides* have not got a trace of those appendages of the vagina, which Reaumur supposed to be male organs. They were not required in her mode of generation, and are not developed. The germ-cell already exists in her, with sufficient spermatic and plastic force for its development; no semen, therefore, was required to be retained, and there is no spermatheca: the embryonic development is completed *in utero*, and no secretion for the protective covering of ova was needed. The structures, therefore, which Reaumur, under a misconception of their nature, cited in order to solve the problem of the alleged virgin procreation, are present only in that perfect form of *Aphis* where no such phenomena are manifested.

Léon Dufour,* whose extent of research and comparison of the generative organs of insects led him to a true appreciation of the nature and function of the appendages to the female organs of the oviparous *Aphides*, referred the phenomena of the generation of the larviparous *Aphides* to "spontaneous or equivocal generation." Now, if we consider what we actually learn from these words,—that the larvæ produced by the virgin Aphides are produced by "spontaneous" or equivocal generation,—it will seem to be little more than another mode of stating the fact. The condition or mode of the fact, the phenomena rendering it possible, are not explained by them; M. Léon Dufour, however, meant to record his belief in a hypothetical mode of generation, in which, as he expresses it, "the act of impregnation was in no degree concerned." Having detected the male Aphis, and well scrutinised the structure of its organs, having witnessed the coitus with the winged female, and carefully excluded the male in repeating the observations and experiments of Bonnet, M. Dufour satisfied himself, and affirmed, that impregnation had no share whatever in the phenomena of the development of the larval aphis in the body of another virgin larval aphis.

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* CCLVII.

With regard to the hypothesis of spontaneous generation, the reasons which have led me to concur with most physiologists of the present day in rejecting it were fully given in a former Course of Lectures on the subject of Generation, and every exact observation and experiment subsequently recorded serve to render that hypothesis less tenable and more gratuitous.

Professor Morren, a comparatively recent and very exact observer of the anatomy and generative economy of the *Aphides*, retaining the hypothesis of spontaneous generation as it has been applied to the Entozoa, propounded, though not without reserve, a theory that the larval aphides were developed in the body of the virgin parent, like Entozoa, "by the individualisation of a previously organised tissue." Now here also is a phrase which, when the meaning of it is analysed, does little more than express the old facts in a new way. When a larval aphis is developed, a new individual exists; in other words, it has been "individualised;" and, as nothing can come out of nothing, it must have been by the individualisation of a previously existing something. The question to be solved is, what is that something, and what has happened to that something to make its individualisation under the form of a larval aphis possible and conceivable by us according to the known analogies of other embryonic developments or individualisations? That would be the explanation of which we are in quest,—an explanation going as far as that which we are able to give, for example, of the development of an ordinarily impregnated ovum; and, by the [illegible] essential condition of the development [illegible] that condition in the impregnated ovum [illegible] advance of knowledge of the operation [illegible] applied to it.

When, however, M. Morren [illegible] comme chez quelques [illegible] précédemment organisé * [illegible] one has ever [illegible] or other organised [illegible] zoon: such a [illegible] cordance with [illegible] the abstract. In [illegible] rous nucleated cells [illegible] can produce [illegible] which products are [illegible]

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* [illegible]

Before entering upon the anatomy of the typical forms of the *Arachnida*, a few remarks may be premised on another low-organised member of the class, which, on account of its remarkable power of retaining life, and reviving after some years' complete desiccation, has received the generic name of *Macrobiotus*. This minute and peculiarly shaped mite, in which the hinder rudimental legs come off from the abdomen, was discovered by Eichhorn in 1767 *, and was described by him under the name of "water-bear" (wasser-baer). Corti, in 1774 †, recounted its power of returning to life after being dried. It is not uncommonly found in the gutters of the roofs of continental houses; it crawls along the sediment like a tortoise, and was grouped by Spalanzani ‡ with the Rotifers, under the name of "tardigrade." Otho Fred. Müller § first detected its true relationship with the mites. It is subject to many moults and oviposits in its exuviæ, which, as the integument is chitinous, is long preserved from decay. The transparency of the skin is such, in the living animal, as to show a complicated muscular system beneath, the ultimate fibre of which is smooth. The nervous system consists of four ganglia, corresponding with the four segments of the body; there is no superœsophageal ganglion. The mouth is suctorial, situated at the end of a retractile proboscis, on each side of which are two tooth-like styles, — the rudiments of lateral jaws. The stomach is oblong, occupying a large portion of the body, and is divided by numerous constrictions into irregularly disposed cæca; their walls are provided with hepatic cells. Near the mouth are two large lobulated glands, that seem to be salivary. No traces of respiratory organs have yet been found; and the respiration in *Macrobiotus*, as in *Demodex*, must be cutaneous.

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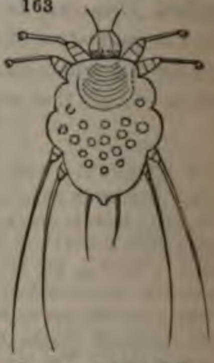

Sarcoptes Galei, or itch-insect, magnified.

In some of the small and parasitic tracheary Arachnids or mites, certain pairs of legs are terminated by adhesive suckers, and others are occasionally terminated by setæ, as in the itch-mite (*Sarcoptes Galei*, *fig.* 163.).

The mouth, in all Arachnids, is situated on the anterior segment, and is provided with instruments adapted either for suction or mastication. In the parasitic mites the rudiments of the jaws are more or less enveloped in a sheath formed by the lower lip: the maxillary palpi are usually the only parts which have free and independent movements, and their extremity is commonly armed either with a hook or with a pair of small nippers.

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* CCLXXXII.

† CCLXXXIII.

‡ XLIII.

§ XLIV.

In spiders the parts called mandibles (*fig.* 172, *a*) are situated at the front of the head and are terminated by a moveable and very sharp hook, which is pierced at its extremity by a small fissure, serving to give issue to the poison secreted by a gland lodged in the preceding joint. The maxillæ (ib. *b*, *b*) are two in number, and the labium (ib. *e*) situated between these organs is composed of a single piece. The maxillary palpi (ib. *c*), compared with those of insects, are of great length and size, and resemble the thoracic feet, which, in the Mygale, they nearly equal in length. In female spiders they are terminated by a single moveable claw: in the males the last joint (ib. *d*) is dilated, and presents a more complicated structure. In the scorpion the mandibles (*fig.* 164, *a*) are short, and terminate in a pair of strong pincers: the maxillary palpi (ib. *b*) are proportionally more developed than in the spiders, and, like the mandibles, they terminate by pincers, which are so strong and large in the great scorpion (*Buthus Africanus*), as to resemble the chelæ of the Crustacea, and more especially as they are succeeded by four pairs of simple and smaller thoracic legs.

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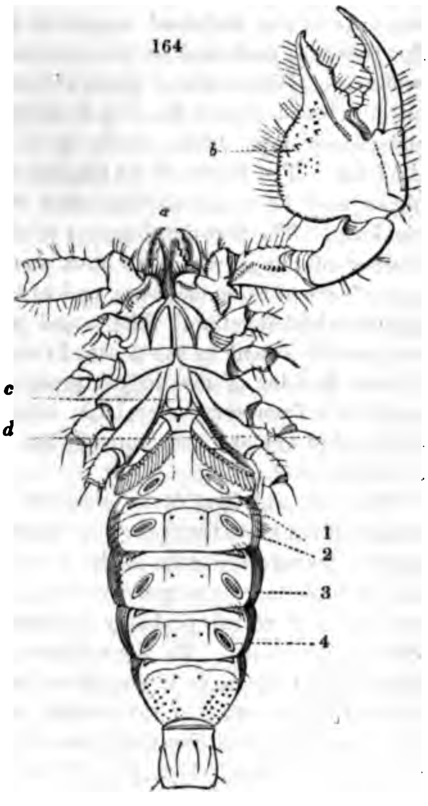

In the genus *Galeodes* the mandibles are chelate, but much longer and larger than in the scorpions. The maxillary palpi resemble small slender feet, but without the terminal hooks; and the succeeding pair of appendages being similarly modified, only six ambulatory feet of the ordinary structure remain. Two rudiments of antennæ have been noticed attached to the mandibles in certain species of this genus. The head is likewise more distinct from the thorax, and it supports the first of the four pairs of legs usually ascribed to the Arachnids. These modifications, with the union of the ocelli into two groups, indicate the Galeodes to form the passage to the Hexapod insects.

The modification and the connections of the pair of appendages which succeeds the maxillary palpi in the Galeodes demonstrate that they are the homologues of the labial palpi in Hexapod insects. In most spiders they are explorers, and are carried forwards extended, while the other legs are used in progression. The position of the rudimental antennæ in the same interesting genus confirms the indication afforded by the nervous system in spiders and scorpions, that the antennæ are confluent with the so called mandibles, if these be not altogether modified antennæ. They are not the homologues of the mandibles of insects.

In the composition of the cephalothorax of spiders the tergal elements of the coalesced segments are wanting, and the back of the thorax is protected by the elongation, convergence, and central confluence of the epimeral pieces; the sternal elements have coalesced into the broad plate (*fig.* 172, *h*) in the centre of the origins of the ambulatory legs, from which it is separated by the episternal elements. The traces of the original separation of the four epimeral pieces may be easily distinguished in some spiders, as in *Pholcus rivulatus.* The non-development of the tergal elements explains the absence of wings, which we have seen, in the *Articulata,* to be the appendages of those elements, and to be very frequently restricted to the branchial function. The tergal parts of the thoracic segments are equally absent in the decapod Crustacea; but, in them, the back of that division of the body is protected by the carapace, continued backwards from certain cephalic segments: when this is raised, the epimeral pieces are seen converging, as in spiders, but not meeting and coalescing.

The soft and flexible integument of the abdomen in mites and spiders gives no indication of the segments or their component parts, but it is favourable for the study of its intimate organisation. Beneath the epiderm and pigmental layer may be distinguished a thin chorion, the fibres of which, probably contractile, surround the abdomen in various directions. To the epiderm belong the hairy and spinous appendages: the large bird-spiders (*Mygale*) are clothed with a thick coat of hair: some of the smaller species, as *Aranea domestica,* have complex hairs, like the down of birds, implanted by a stem. In other spiders, similarly implanted stems support scales, analogous to those of the *Lepidoptera;* the bright colours of the *Salticæ* and *Oxyopes* are due to these scales.

The dense chitinous covering of the cephalothorax in the great tropical spiders (*Mygale*), and of a larger proportion of the skeleton in the African scorpion, consists of a series of layers of a brown colour; the superficial are darker than the rest: the layers are traversed, in the scorpions, by minute tubes.*

The legs, answering to the six in hexapod insects, consist each of a *coxa*, a short *trochanter*, a longer stiff *femur*, a *tibia* divided by an articulation into two unequal parts, and a *tarsus* composed of a long and short joint; the latter is commonly armed by two claws. In some spiders these have a pectinated appendage on their convex side. There is a spine on the end of the tarsus of each hind leg opposed to the terminal hooks. In the aquatic *Hydrachnæ* the legs are thickly set with hairs on one side.

The muscular system is principally aggregated in the cephalothorax for working the organs of mastication and locomotion: some small muscular bands are attached to a median ventral raphé of the abdomen in certain spiders. There are better developed muscles in the slender jointed abdomen of the scorpions for its inflection and extension, and more especially for the purpose of wielding the poisonous weapon with which it is terminated. The elementary muscular fibres are transversely striated.

A well-marked gradation of structure may be traced in the nervous system of the Arachnids. The brainless condition of *Macrobiotus* has already been alluded to. In the *Pycnogonidæ* the first of the four ventral ganglions is connected by a slender œsophageal collar with an ovoid cerebral ganglion; this is divided in the *Phalangidæ*.

The principal masses or ganglions of the nervous system are concentrated around the œsophagus in the cephalothorax of the scorpion. From the small supercœsophageal or cephalic bilobed mass are sent upwards the optic filaments, forwards the nerves of the forcipated mandibles or "chelicera," and, backwards, the stomato-gastric nerves; the sub-œsophageal ganglionic columns distribute nerves to the great maxillary cheliform palpi, and to the four pairs of thoracic legs: two slender continuations of the median columns are continued along the jointed abdomen or tail, and seven small ganglions are developed upon them, from which and from the interganglionic chords nervous filaments are distributed to the surrounding parts.

The ventral continuation of the anterior aorta, which lies loosely upon the dorsal aspect of the ganglionic chords, must be injected in order that its branches, which accompany the nervous filaments, may be distinguished from them. The vessel itself has been mistaken for a nerve, and has been regarded by some as the motor, by others as the respiratory tract.

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* CCXXXI. p. 405.

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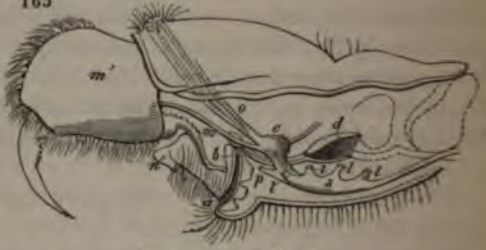

Nervous system, Mygale.

In spiders the central masses of the nervous system are wholly, or in great part, concentrated in the cephalothorax. The brain (*fig.* 165, and 166, *c*) is a bilobed ganglion, sending forwards and upwards the optic nerves (*o*) from its anterior angles, and below these, the two large nerves (*m*) to the mandibles (*m'*): a short and thick collar encloses the narrow gullet, and expands into a second very considerable stellate or radiated ganglion (*s*), situated below the stomach upon the plastron: it sends off five principal nerves on each side; the first (*p*) to the pediform maxillary palpi; the second (*l*) to the more pediform labial palpi, which are usually longer than the rest of the legs and used by many spiders rather as instruments of exploration than of locomotion: the three posterior nerves (*l*, *l*, *l*) supply the remaining legs, which answer to the thoracic legs of Hexapod insects. The nervous axis is prolonged beyond this great ganglion, as two distinct chords, into the beginning of the abdomen, where, in the *Epeira diadema*, it divides into a kind of cauda equina; but in the *Mygale* a third ganglion of very small size is formed, from which the nerves diverge to supply the teguments of the abdomen and its contents. The origin of the mandibular nerves close to the optic ones from the superœsophageal ganglion strongly indicates the antennal relations of the mandibles, whilst the homologues of the maxillary and labial palpi receive, as in insects, their nerves from the subœsophageal mass. The stomato-gastric nerves are sent off from the posterior and lateral parts of the brain, and form on each side a reticulate ganglion, which distributes filaments to the stomach.

Many of the lower parasitic species of arachnids are blind: not any of this class have compound eyes, but *Galeodes* and *Pholcus* have their ocelli arranged in two lateral groups. The scorpions have eight ocelli, two of which are situated near the middle line, and three on each side near the anterior angles of the cephalothorax.

In the spiders the ocelli are generally arranged in a group, upon an eminence at the middle of the anterior part of the cephalothorax; they are generally eight, never less than six in number. The position of the four median ones is the most constant; they generally indicate a square or a trapezium, and may be compared with the median ocelli in hexapod insects. The two, or the two pairs of lateral ocelli may be compared with the compound eyes of insects; the anterior of these has usually a downward aspect, whilst the posterior looks backwards; the variety in the arrangement of the ocelli of spiders always bears a constant relation to the general conformation and habits of the species. Dujès has observed that those spiders which hide in tubes, or lurk in obscure retreats, either under-ground or in the holes and fissures of walls and rocks from which they only emerge to seize a passing prey, have their eyes aggregated in a close group in the middle of the forehead, as in the bird-spider (*fig.* 165), the clothos, &c. The spiders which inhabit short tubes, terminated by a large web exposed to the open air, have the eyes separated, and more spread upon the front of the cephalothorax. Those spiders which rest in the centre of a free web, and along which they frequently traverse, have the eyes supported on slight prominences which permit a greater divergence of their axes; this structure is well marked in the genus *Thomisa*, the species of which lie in ambuscade in flowers. Lastly, the spiders called *Errantes*, or wanderers, have their eyes still more scattered, the lateral ones being placed at the margins of the cephalothorax. The structure of these simple eyes resembles that which has been so well described by Müller in the scorpion; Lyonnet had recognised the crystalline lens. The iris, or process of pigment which advances in front of the lens, is green, red, or brown in the diurnal spiders, and black at the back part of the eye. The nocturnal species, as *Mygale* and *Tarantula*, have a brilliant tapetum, but no dark pigment.

In the scorpion the transparent prominence which indicates each ocellus is a thick dermal cornea, not divided into facets; it is deeply excavated at the middle of its inner surface for the lodgment of the spherical lens: the back part of this body rests upon, without sinking into, the anterior surface of a hemispherical vitreous body. The interspace between this body and the lens forms a circular channel filled with aqueous humour and receiving a circular process of the thick pigmental chorion which defines the pupil and confines the lens to the anterior chamber. The pigment coats the retina and covers part of the optic nerve.

Spiders have the sense of hearing, but neither the organ nor its situation are known. The same may be said of the sense of smell. The membrane lining the mouth and pharynx may have the faculty of taste, and influence the Arachnids in their choice of food. The soft and often hairy integument must be to a certain degree sensitive, but touch would appear to be exercised principally by the leg-like instruments into which the maxillary and labial palpi are converted.

The *Saltatores* have the terminal joint of the palpi abundantly beset with hairs, and use them to brush off dust or other extraneous matters from the anterior eyes: requiring distinctness of vision to make their sudden springs available in seizing their prey.

The alimentary canal is short and straight in most Arachnids: a slight convolution of the intestine takes place in some spiders: that of mites is straight and wide, but the stomach, in some which have the anus near the middle of the abdomen (*Erythreus*), is produced into lateral sacculi; these are bifurcated in *Ixodes*. In the *Pycnogonidæ* the long and slender gastric cæca penetrate the chelicera, and the eight long and slender legs, as far as the end of the tibia. In scorpions, the alimentary canal extends, without any gastric dilatation or intestinal convolution, from the mouth to the anus. Five short and straight diverticula are sent off at equal distances from each side of the thoracic portion, and are lost in the granular and seemingly adipose masses, which have been regarded as a kind of epiploon by some, by others as an hepatic organ. Two delicate capillary renal tubes unite on each side, close to the intestine, and open into that part of the canal which is in the anterior part of the tail-like abdomen.

The spiders are remarkable for the minuteness of the pharynx and œsophageal canal. Savigny believed that in some species there existed three pharyngeal apertures, through which the juices, expressed from the captured insect by the action of the maxillary plates (*fig.* 165, *n*) were filtered, as it were, into the narrow œsophagus. In the Mygale, however, there is certainly but one aperture: this is defended above by a horny plate, or rudimental labrum; below by the labium, which is soldered to the plastron in the Mygale, but jointed and movable in most of the smaller spiders.

The pharyngeal fissure (*fig.* 165, *b*) ascends between an anterior convex plate or palate and a posterior concave plate, both of which are shed and renewed at each moult. The slender œsophagus passes backwards at a right angle to the pharynx, perforates the nervous ring, and expands into the stomach (ib. *d*). In the house-spider (*Tegenaria domestica*), the gastric cavity is produced into four sacs, which are susceptible of great distension when a large prey is captured. In another species of spider (*Pholcus rivulatus*), the œsophagus (*fig.* 166, *a*), having passed under the brain (*c*), suddenly expands into a stomach, almost as broad as the sternum, which sends off a long clavate cæcal process into the base of the maxillary palpi (*e*), and of each thoracic leg (*e'*). A shorter diverticulum (*d*) is continued from the upper part of the stomach. The intestine is contracted where it passes through the pedicle of the abdomen; it slightly expands in its straight course (*f*) along the anterior part of that cavity, then contracts and forms two short convolutions (*g*), and communicates with a large globular cæcum (*h*), from which the short rectum passes to the vent. In some mites, *e. g. Ixodes*, the salivary glands consist of masses of vesicles situated on the sides of the fore part of the body; and pour the secretion by branched canals into the mouth at the base of the labium. In the spiders a slit in the upper lip leads into a cavity at the base of which is a transparent glandular mass, the secretion of which flows through the slit, and moistens the substances from which the nutriment is being extracted. Four biliary ducts (*i*, *i*) open into each side of the straight portion of the intestine. Two longer and more slender urinary tubes (*k*, *k*) communicate with the beginning of the cæcum, which seems to stand to them in the relation of an urinary bladder. Large masses of adipose epiploon occupy, in well-fed spiders, the sides of the abdomen, and cover and conceal the granular brownish cæcal terminations of the voluminous hepatic organ.

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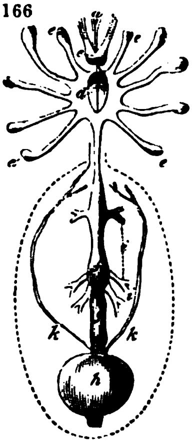

Alimentary canal, Spider. *Pholcus.*

The gastric cæca and the stores of fat may both contribute to the power of endurance of the prolonged fasts for which spiders are remarkable. Mr. Blackwall kept a young *Theridion* 4-*punctatum* alive without food from the 15th October, 1829, to the 30th April, 1831. It had alvine evacuations at distant intervals and in small quantities to the end of its existence. It also spun several snares, which were successively removed by the experimentor.

The chyle is received immediately by the veins, and conveyed to the dorsal vasiform heart. The heart is situated in all Arachnids, as in the other Articulata, beneath the dorsal integument and above the alimentary canal. In the *Phalangidæ* it is three-chambered*: in the scorpions it is confined to the six dilated anterior segments of the abdomen, where it is of uniform diameter, except at its two attenuated extremities: it receives the venous blood from the surrounding pericardial sinus by ten or eleven pairs of apertures, each guarded by a pair of valves. From the anterior and larger extremity the anterior aorta is continued, which is short, and soon divides into three branches: a longer and more slender vessel is continued along the terminal segments of the abdomen from the narrower posterior end of the heart.

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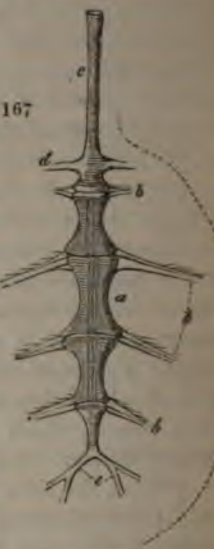
* CCLXV. p. 154.

In the spiders the heart (*fig.* 167, *a*) extends, as in flying insects, along nearly the whole of the abdomen, but is wider than in the scorpion or in insects. It is fusiform, with thick walls, composed chiefly of transverse muscular fibres, slightly decussating on the inner surface: a narrow strip of longitudinal fibres extends along the middle of the dorsal surface.



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Heart of Spider. *Pholcus.*

The blood is returned to the heart either by from four to six pulmonic vessels (*b*, *b*) on each side, or by the great sinus that surrounds it like a pericardium, or by both ways. It is propelled forwards by the contraction of the muscular walls, which action can frequently be discerned through the thin integument of the smaller spiders. M. Dugés*, who succeeded in throwing a solution of carmine into the heart from behind forwards, affirms that it flowed readily by the lateral pulmonic vessels (*b*, *b*) to the base of the pulmonary lamellæ, and that these productions of the breathing sacs were coloured rose-red by the injection of their capillaries. Hence he concluded that those vessels were pulmonic arteries. M. Blanchard†, who has equally succeeded in injecting them, deems them to be veins, and the sole channels by which the blood returns to the heart. The disposition of the venous pericardial sinus inclines me, however, to believe that the heart serves the purposes of both pulmonic and systemic circulations, as Hunter discovered to be its function in the flying insect. An artery is continued from both extremities of the heart; the anterior aorta (*c*) gives off two transverse branches (*d*), the posterior vessel soon divides into the genital arteries (*e*). It sends off an inferior branch to the intestine, and, having penetrated the thorax, it gives two branches, which divide to supply the gastric cæca. It then divides into two branches, which run forward nearly parallel to the brain and eyes; supply the chelicers and the poison-organ of that part; and bend down to become intimately blended with the subœsophageal nervous mass. The arteries have few ramifications, are usually short, and soon lose themselves in the diffused venous sinuses. The venous apertures are bivalvular, as in the heart of the scorpion. The blood contains colourless round corpuscles, which have been seen to circulate in the limbs of young

* CCLXXIII. † CCLXXVIII.

spiders; returning by a less regular channel than the arterial one: the veins of the great cavities of the body are irregular and wide sinuses.

All true Arachnids breathe the air directly: the tracheary respiratory apparatus of the mites commences by a few, usually two, orifices, sometimes concealed between the anterior feet (*Trombidium*); sometimes very apparent above the third pair of legs (*Gamasus*); sometimes behind the last pair of legs. In *Demodex*, the *Tardigrada*, and *Pycnogonidæ*, no traces of respiratory organs have yet been found. In the species, parasitic on the hedgehog (*Ixodes Erinacei*), there are three stigmata; two near the sides, and one below, at the middle of the abdomen: the latter is described by Audouin as a spherical tubercle, pierced by a number of minute holes, by which the air penetrates the tracheæ. They usually arise by a simple tuft from the two stigmata: in *Gamasus*, there are given off from the tufts two unbranched tracheæ, which course along the sides of the cephalothorax, and terminate in cæca at the base of the mouth. The tracheæ are very delicate, and their spiral filament discernible only in the larger kinds of mite. Those of the water spiders (*Hydrachna*) doubtless act, like the branchi-tracheæ of aquatic insect larvæ, in extracting the air from the water.

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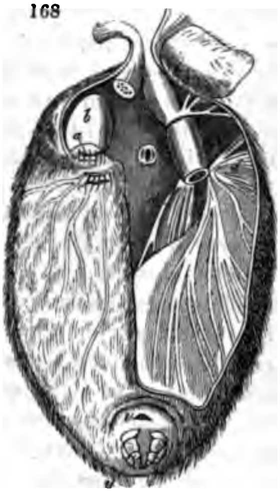

Respiratory organs, Segestria.

The spiders of the genera *Segestria* and *Dysdera* have four stigmata, situated on the under and anterior part of the abdomen: the anterior one on each side (*fig.* 168, *a*) is the aperture of the pulmonary sac (*b*); the lower orifice (*c*) leads to a short and wide cylinder, from which radiate numerous tracheæ (*d*) having the usual shining surface. These tubes are united together in bundles, and diverge to the surrounding parts by dissociation, not by true ramification, like the tracheæ of mites and insects. One bundle is dispersed throughout the abdomen; another enters the cephalothorax and resolves itself into groups corresponding in number with the limbs to the extremity of which the fine silvery tracheæ can be traced. In *Epeira* and some other spiders there is a transverse fissure in front of the spinnerets, from which a short tracheal trunk proceeds: this sends off four simple flattened tracheæ, devoid of the spiral filament, which extend, gradually attenuating to the base of the abdomen.[*] The pulmonary sac (*figs.* 168, 170, *b*), which receives the air by the anterior respiratory orifice, is of an elliptical form; the vascular surface is augmented by a number of broad and close-set lamellæ which project into its interior.

In the scorpion (*fig.* 164), the stigmata or pulmonary orifices are eight in number, four on each side of the under surface of the anterior broad segments of the abdomen (1, 2, 3, 4). They have the form of oblique fissures, surrounded by a thickened margin, to which the name of "peritrema" has been given. The vascular lining membrane of the cavity adheres to this margin, and is at first simple, but afterwards gives attachment to a series of twenty broad and close-set lamellæ, arranged, as in the spiders, like the leaves of a book. The genus *Phrynus* has only two pairs of pulmonary sacs; but each sac has eighty lamellæ.

The peculiar organs of secretion in the class *Arachnida* are those which prepare the material of the web, which is analogous to silk, and those which secrete the venomous liquid. The former are proper to spiders; the latter common to both spiders and scorpions. The modification of the abdominal segment of scorpions, by which its hinder half is converted into a slender, jointed, flexible, tail-like appendage, seems to have special reference to the wielding of the envenomed sting. The glands which supply this weapon with its poisonous fluid are lodged in that well-known pyriform dilatation formed by the last joint of the tail, and which is terminated by the slender, sharp, recurved sting.[†] A minute slit may be observed near the point, which is the common outlet of two slender ducts, that gradually dilate into two secreting sacs, lodged in the cavity of the expanded part of the joint, and separated from each other by a double vertical partition. Their chief tunic is formed by a layer of smooth muscular fibres, external to which is a stratum of cylindrical cells.

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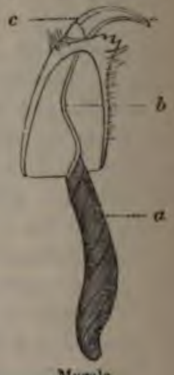

Mygale.

The poison-apparatus of spiders is placed at the opposite extremity of the body. The perforated sting or fang forms the second joint of the mandible or modified antenna, upon which it has a gynglymoid movement, and lies concealed and protected, when not in use, in a furrow with dentated margins upon the basal joint (*fig.* 165, *m'*). The poison gland (*fig.* 169, *a*) is an elongated ovoid vesicle, the exterior of which is characterised by spiral folds produced by the arrangement of the fibres of the contractile tunic. The duct (*b*) traverses the basal joint of the mandible and the cavity of the fang (*c*), and terminates in a fissure on its convex surface near the point. In the true *Araneæ*, the *Clubiones*, and the *Lycozæ*, the poison glands extend into the cephalothorax ; but in the bird-spiders (*Mygale*) they are limited to the mandibles. It is probable, therefore, that the effects of a wound occasioned by these gigantic spiders may be exaggerated: those species of our native spiders, which are most formidably armed, cause little or no inflammation in piercing the human skin ; but their poison seems to take fatal effect upon insects. The mechanical laceration, and the sucking out their juices, must, however, be taken into the account of the lethal powers of the spiders as exercised upon their entrapped prey. Litmus paper pierced by the mandibular hooks of irritated spiders becomes red as far as the emitted fluid spreads, showing the poison to be acid.

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[*] XXIV. p. 535.

[†] Prep. No. 2161.

The organs which secrete the material of the web are lodged in the posterior part of the abdomen, and in *Epeira fasciata*, which is remarkable for the large size of its web, they occupy, when in full activity, about one fourth of the abdominal cavity. They present the form either of slender and more or less branched tubes, or of dilated sacs, the excretory ducts of which terminate upon projecting jointed organs at the posterior extremity of the abdomen, called spinnerets (*fig.* 172, *u*).

In the *Clubiona atrox* the glands consist of four larger and numerous smaller tubes: two of the larger branched tubes are twice the size of the other pair. In the genus *Pholcus* (*fig.* 170) the organ is reduced to a more simple condition ; it consists of six vesicles of different shapes and sizes; two (*q*) are large and elongated; they occupy the middle of the under part of the abdomen, and their slender ducts are continued in a tortuous course to the spinnerets ; two others (*r*) are also elongated, but are smaller than the preceding; the remaining two are spherical (*s*). The duct of each of these glands terminates upon its appropriate spinneret, and there are consequently six of these organs.

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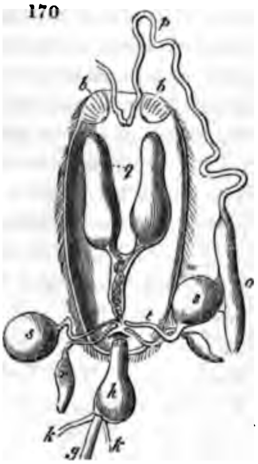

Pholcus.

Mygale avicularia has only four spinnerets, and in *Mygale cementaria* two of them are imperforate. *Clubiona atrox* and some species of *Drassus* have eight spinnerets; the two accessory ones being situated in advance of the rest, and connected, in *Calamistrum*, with a kind of comb attached to the metatarsus of the hind legs. Six, however, is the ordinary number of spinnerets in the spiders, two of which are longer than the others. The secretion does not issue by a simple outlet, but by a multitude of microscopic pores (*fig.* 171), which, in the shorter pairs of spinnerets, are prolonged from the terminal surface upon minute processes. If you throw a little dust upon the web of any of the orbitele spiders, of the *Epeira diadema* for example, you may observe that it adheres to the spiral, but not to the radiated, threads; for the spiral thread is beset with minute viscid globules. Lyonnet supposed that the adhesive threads issued from the tubular, and the others from the sessile orifices. The secretion is a glutinous fluid, insoluble in water, and quickly drying in air; some species, as *Argyroneta aquatica*, spread their nets habitually under water.

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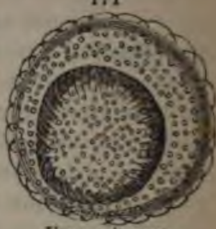

Upper spinneret.
Tegenaria civilis.

The degree and mode in which spiders exercise this singular secreting faculty varies considerably in the different species. Some, as the *Clubiones*, line with silk a conical or cylindrical retreat, formed, perhaps, of a coiled-up leaf, and having an outlet at both extremities, from one of which may issue threads, to entrap their prey. Others, as the *Segestriæ*, fabricate a silken burrow of five or six inches in length, in the cleft of an old wall. The *Mygale cementaria* lines a subterraneous burrow with the same substance, and manufactures a close-fitting trap-door of cemented earth lined with silk, and so attached to the entry of the burrow as to fall down and cover it by its own weight, and which the inmate can keep close shut by means of strong attached threads.

The arrangement of spiders by M. Walcknaër* into families, characterised by their habits, places the principal varieties of their webs in a very concise point of view.

The *Cursores*, *Saltatores*, and *Laterigradæ*, make no webs; the first catch their prey by swift pursuit, the second spring upon their prey by insidious and agile leaps; the third run, crab-like, sideways or backwards, and occasionally throw out adhesive threads to entrap their prey. The *Latebricolæ* hide in burrows and fissures, which they line with a web. The *Tubicolæ* inclose themselves in a silken tube, strengthened externally by leaves or other foreign substances. The *Niditelæ* weave a nest, whence issue threads to entrap their prey. The *Filitelæ* are remarkable for the long threads of silk which they spread about in the places where they prowl in quest of prey.

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* Histoire des Araneïdes.

The *Tapitelæ* spin great webs of a close texture like hammocks, and wait for the insects that may be entangled therein. The *Orbitelæ* spread abroad webs of a regular and open texture, either circular or spiral, and remain in the middle, or on one side, in readiness to spring upon an entangled insect. The *Retitelæ* spin webs of an open mesh-work, and of an irregular form, and remain in the middle or on one side, to seize their prey. Lastly, the *Aquitelæ* spread their silken filaments under water to entrap aquatic insects.

The silken secretion of spiders is not applied only to the formation of a warm and comfortable dwelling for themselves, or of a trap for their prey; it is often employed to master the struggles of a resisting insect, which is bound round by an extemporary filament, spun for the occasion, as by a strong cord. It forms the aëronautic filament of the young migratory brood. It serves to attach the moulting Hydrachna to an aquatic plant by the anterior part of the body, when it struggles to withdraw itself from its exuvium. Lastly, a softer and more silken kind of web is prepared for the purpose of receiving the eggs, and to serve as a nest for the young.

The lower forms of the Arachnids, e. g. *Macrobiotus* and *Acaridæ*, are remarkable for their great longevity and their power of retaining latent life. Some spiders live only twelve months; others, e. g. *Segestria senoculata*, do not reach maturity until two years old.

The *Macrobiotus* is androgynous, and the only known arachnid that is so. The testes are two long fusiform sacs, situated one on each side of the single ovarium and of the intestine; they communicate with a median dorsal vesicula seminalis, in which Doyère and Dujardin have detected actively moving spermatozoa. The ovarium is a large sac, with loose and dilatable tunics, situated dorsad of the intestine and advancing, when gravid with ova, as far forwards as the first segment of the trunk. A short oviduct opens at the fore part of the cloaca, which is on the ventral aspect of the penultimate segment. The ovarian sac is sustained by two suspensory ligaments or muscles, which diverge to be attached, above the gastric division of the alimentary canal, to the internal dorsal muscle of the second segment. The ova, which are usually five or six, rarely more than ten in number, are simultaneously developed, and of large proportional size. The clear germinal vesicle is imbedded in a coloured yolk, enclosed in a membrana vitelli. When oviposition and moulting go on together, and the cast skin receives the eggs, the chorion is smooth: at other times the chorion is beset with points or tubercles. The germ-mass is transformed at once into the Macrobiotus; the young animal moves on the twentieth day, and is excluded on the twenty-fourth, unless it happens to become dried, when the young becomes torpid like the parent, and both revive when they are re-moistened. It is about one-fourth the size of the parent.

All the Arachnids of the mite family are remarkable for their power of resisting lethal influences, and for the retention of their vitality when torpid and apparently dead. The ova of such are, with still greater difficulty, deprived of their latent life. As all the mites have been endowed with well-developed, if not complex, generative organs, the requisite proof must be satisfactorily afforded of the impossibility of the existence of the eggs of mites in, or of the access of such to, fluids traversed by galvanic currents, before credence can be reasonably given to the statements that acari have been developed by such agency, without any pre-existing egg, *i. e.* by way of the "*generatio spontanea seu equivoca.*"

In the genus *Trombidium*, the species are, as in other true mites, represented by distinct males and females; the testes form one compact mass, consisting of a group of red-coloured sperm sacs, attached by a short stem to an annular vas deferens, which opens between the hindmost pair of legs, but receives before its termination the ducts of two vesiculæ seminales. In the female the ovarium is large and apparently single, but from it there proceed two oviducts. Mites are oviparous; the eggs of the *Acarus* or *Sarcoptes Galei*, have been detected beneath the epiderm, in itch-patients. The females of the *Pycnogonidæ* are known by their filiform jointed ovicapsules, situated in front of the first pair of legs.

In the true spiders (*Araneidæ*) the males are characterised by their smaller size, their longer limbs, and brighter colours, as compared with the females; but more decisively by the tumid and unarmed termination of the long maxillary palpi; the parts analogous to "vesiculæ seminales" being lodged here. The essential and the accessory generative organs of this sex are quite distinct and remote from each other: the principle of such separation, which is exemplified in the relation of the Fallopian tube to the ovarium in Mammalia, is carried to an extreme in regard to the vesicula seminalis and testis in the spiders. If the analogy of the female parts be here, as in other animals, a guide in the determination of the essential organs of the male, the testes ought to be the two long vermicular tubes, applied to the under wall of the abdomen, which commence posteriorly, either by a simple sac, as in the Mygale, or by an oblong vesicle, as in the genus *Pholcus*, the ducts of both of which terminate anteriorly by two approximate orifices, or else by a common opening, as in *Tegenaria* (*fig.* 172, *k*), situated between the two pulmonary stigmata (ib. *i*, *i*). These abdominal testicular sacculi are, in fact, laden at the breeding season with sperm-cells and their characteristic nuclei or "spermatoa," from which the spermatozoa are afterwards developed.

The second or copulatory part of the generative organs is confined to the two last joints of the maxillary palp (ib. *c*, *d*); the dilatation of these joints is chiefly formed by a spoon-shaped membranous tube or sac, commencing at the penultimate and reaching its greatest expansion at the last joint (*d*): this tube appears to line a cavity in the ordinary state; but it can be distended, everted, and erected, when it is seen to be terminated by a horny appendage. In this sac the spermatozoa are found both free, and in the interior of the sperm-cells, having escaped from the spermatoa into the cavity of the parent sperm-cell.

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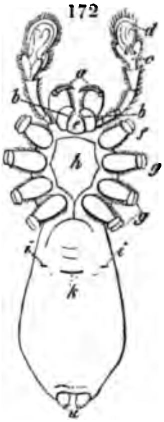

Tegenaria domestica.

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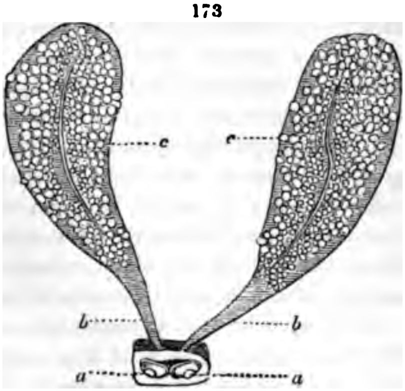

Epeira diadema. Female organs.

In the female spider the ovarium sometimes presents the form of a simple elongated fusiform vesicle (*fig.* 170, *o*), closed at one extremity and communicating with a slender oviduct (*p*) at the other, which duct, after more or fewer convolutions, terminates at the corresponding angle of the simple transverse vulva. It is situated, like the outlets of the vasa deferentia, between the pulmonary stigmata (*b*, *b*). Each ovarium (*fig.* 173, *c*) is divided in the Epeira, or diadem-spider, by a median septum, and the eggs are laid at two distinct periods. The ducts (*b*) are short, and terminate each by a distinct orifice (*a*) within the transverse vulva. In the common house spider the ovisacs are developed, like grapes, from a central stem-like ligament, to which they are appended by slender peduncles, the whole being inclosed in the common capsule. The short vagina or vulva receives the ducts of two sperm-reservoirs; they are of a brown colour and horny texture, and are attached to the skin.

Their ducts are sometimes long and intertwined; e. g. *Salticus, Thomisus.*[*]

The most careful observations, repeated by the most attentive and experienced entomologists, have led to the conviction that the ova are fertilised by the alternate introduction into the vulva of the appendages of the two palpi of the male. Treviranus's supposition that these acts are merely preliminary stimuli, has received no confirmation, and is rejected by Dugés, Westwood, and Blackwall; and with good reason, as the detection of the spermatozoa in the palpal vesicles has shown. At the same time, the most minute and careful research has failed to detect any continuation of the vas deferens into the terminal erectile sac of the palp, or any other termination than the abdominal opening above described. Dugés offers the very probable suggestion that the male himself may apply the dilated cavities of the palpi to the abdominal aperture, and receive from the vasa deferentia the fertilising fluid, preparatory to the union; and the discovery of the spermatozoa at an earlier stage of development in the abdominal testes, which development is completed after the transference of the semen to the vesiculæ, equally demonstrates the respective shares which the two widely separated parts of the male apparatus perform in these remarkable Articulate animals. The analogy of the separate location of the testes and vesiculæ seminales in the dragon-fly will no doubt present itself to the mind. Certain it is that an explanation of this singular condition of the male apparatus, in which the intromittent organ is transferred to the remote and outstretched palp, is afforded by the insatiable proneness to slay and devour in the females of these most predacious of articulated animals.

The young and inexperienced male, always the smallest and weakest of the sexes, has been known to fall a victim, and pay the forfeit of his life for his too rash proposals. The more practised suitor advances with many precautions, carefully feels about with his long legs, his outstretched palpi being much agitated; he announces his approach by vibrating the outer border of the web of the female, who answers the signal, and indicates acquiescence by raising her fore-feet from the web, when the male rapidly approaches; his palpi are extended to their utmost, and a drop of clear liquid exudes from the tip of each clavate end, where it remains attached, the tips themselves immediately coming in contact with a transverse fleshy kind of teat or tubercle protruded by the female from the base of the under side of the abdomen. After consummation, the male is sometimes obliged to save himself by a precipitate retreat: for the ordinary savage instincts of the female, "etiam in amoribus sæva," are apt to return, and she has been known to sacrifice and devour her too long tarrying or dallying spouse.

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[*] XXIV. p. 547.

There is a redeeming feature, however, in the psychical character of the female spider, in the devotion with which she fulfils all the duties of the mother. But before proceeding with the examples of the maternal instinct, I shall first point out the anatomical character of the generative organs in the scorpion.

The palpi of the scorpion take no share in the formation of the generative system in either sex; both male and female are provided with a pair of peculiar comb-like appendages (*fig.* 164, *d*), attached directly behind the genital aperture (ib. *c*), which is situated at the middle line of the under and posterior part of the abdomen. Müller has observed, that the teeth in the comb of the male scorpion (***Buthus Africanus***) are much more numerous and smaller than those in the female; but the sexes are not otherwise distinguishable outwardly. The males appear to be fewer in number than the females.

Each testis of the scorpion is a long and slender tubulus, which divides, and the divisions anastomose together to form three loops or meshes enveloping the substance of the liver, and connected with its fellow by two transverse canals. A short blind sac (*vesicula*) and a longer accessory glandular tube communicate with the termination of the short sperm-duct. The common duct terminates in an oblong receptacle, the outlet of which is situated close to the corresponding one on the opposite side of the body, at the middle of the under part of the last segment of the thorax. A small crenate papilliform penis projects from the genital orifice.

The tubular oviduct of the female scorpion divides and unites with its fellow through the medium of a third short middle canal, forming three meshes on each side, and a seventh longer anterior loop by the terminal union of the oviducts before they open upon the bivalvular vulva: anterior to their union each oviduct dilates into a sperm-reservoir.

The ovaria consist of lateral appendages going off at right angles from the longitudinal canals, and expanding into elliptical sacculi before communicating with the canals; the ova are developed in the slender blind free extremities or beginnings of the ovaria, and the embryo is developed in the sacculus, the scorpion being viviparous. The course of its development, which would be a subject of great interest, has not yet been traced. In the separate outlets of the sperm-ducts in the male, and of the oviducts in the female, the higher *Arachnida* manifest an analogy with the *Crustacea.*

All spiders are oviparous. The mother prepares a soft and warm nest for the eggs, which she guards with great care. If kept from the male the female will lay infertile eggs, and take the same care of them. The *Lycosa vagabunda* carries her cocoon about with her; if it be removed, and a ball of cotton substituted, she has been known to bestow upon it the same care; but when the cocoon was offered together with the cotton ball, she seldom failed to select her own fabrication. The *Saltica* selects an empty snail-shell for her cocoon, and spins a silken operculum across the mouth. The *Epeira fasciata* encloses her eggs, which are as big as millet-seeds, in a papyraceous cell, surrounded by a cottony covering, which she then suspends by a dozen threads or pillars to a larger chamber of silk. The whole is attached to a branch of a high tree, and is guarded by the mother, who quits it only in extreme danger, and returns when this is past.

Bonnet, finding in his garden the pit-fall of the larva of the ant-lion, took a spider with her cocoon, and threw them in; the spider crawled up the side of the pit, but before she could escape the ant-lion seized the cocoon and tore it from the female; she returned and seized it, and a battle of some minutes ensued. The ant-lion, however, succeeded in mastering the spider and retaining the cocoon. Bonnet then rescued the mother, and placed her at the margin of the pit; but she refused to abandon her offspring, and remained there, passive, as if she had lost everything that was worth living for.

The eggs of most spiders are spheroidal. Prior to impregnation the ovum consists of a yolk and delicate yolk-membrane, containing a large germinal vesicle, whose nucleus shows several nucleoli, and, besides this, a peculiar firm corpuscle, discovered by Siebold * and Von Wittich †, usually consisting of fine concentric layers, more seldom granulated, and disappearing in the fully developed ova.

After one intercourse with the male the *Tegenaria civilis* has been observed to produce several sets of eggs, intervals of ten months occurring between each act of oviposition, and two years elapsing before all the eggs were deposited.

The impregnated ovum of the spider, at its exclusion, consists of a large and finely granular vitellus, invested by the membrana vitelli, which is separated from the chorion by a very thin structure of colourless liquid, analogous to the albumen or the white of the hen's egg. The yolk is generally of a yellow colour; but in some species of spider is grey, white, or yellowish brown. The germinal vesicle has disappeared. An opaque, white, elliptical spot indicates, at this period, the metamorphosed and impregnated centre from which subsequent development radiates. The previous changes which have led to this condition of the excluded ovum, have been ascertained to be due to the attraction and assimilation by the primary germ-cell and its progeny of a small proportion of the yolk, which is thus seen to consist of a germ-yolk and a food-yolk. The subsequent processes, up to the complete formation of the young spider, have been described and figured by the accurate and industrious Herold.*

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* XXIV. p. 543. † CCXC.

The germ-mass consists of derivative germ-cells, like minute opaque whitish granules of smaller diameter than those of the vitellus; in some species Herold observed what he believed to be several germ-spots on different parts of the superficies of the yolk, which rapidly coalesced into one body. Development commences by expansion of the circumference of the germ-mass, which, as it expands, covers the yolk with a semi-transparent thin layer, the basis of the future integument. Herold next describes the granules of the germ-mass as being decomposed into almost imperceptible molecules, in which we may recognise the ordinary result of the fissiparous property of its constituent nucleated cells: their powers of assimilation are at the same time manifested by the changes which they effect in the albumen, at the expense of which they seem, in the first instance, to increase their numbers, and diffuse themselves over the surface of the vitellus. This covering of the yolk Herold calls "coliquamentum." He observes, that the original position of the germ-spot is indicated by a clear, transparent point (hyaline ?); that this point becomes thickened, pearly, and opaque, so as to conceal the subjacent vitelline cells. He calls this the nucleus of the germ or the cambium (*fig.* 174, *a*). A similar change progressively extends over the colliquamentum; and, when one-fourth of the circumference of the yolk is thus covered, the opaque layer has taken on a definite form, resembling the figure 8 (*fig.* 175), the small and anterior division (*a*) being the base of the future head, the posterior and larger one (*b*), of the thorax. A fissure is next observed to divide the cephalic (*fig.* 176, *a*) from the thoracic portion (*b*), the two parts being distinct at this period, and determining the essential nature of the

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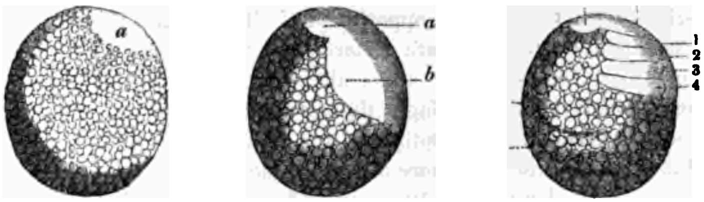

Development of Spider.

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* CCXLI. De generatione Aranearum in Ovo, 1824.

first great segment of the body in the mature spider. The margins of the thorax are next seen to be subdivided on each side by three parallel fissures into four segments (1, 2, 3, 4.); these are the basis of the epimeral pieces. The part of the opaque integument which connects the two series below is the rudimental sternum. A second constriction begins to divide the thorax from the abdomen; the mandibles or antennæ (*fig.* 177, *b b*) begin to bud forth as two convex processes from the anterior part of the head; the part intervening between these and the epimeral pieces forms the rudiment of the maxillæ (*c*).

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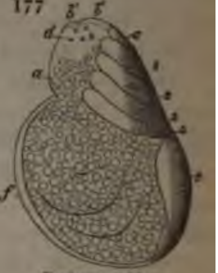

Embryo spider.

The intermediate labium also begins to be defined from the sternum. The opaque peripheral layer (*e*), extending from the thorax to the opposite end of the ovum, lays the foundation of the ventral integument of the abdomen. Upon the opaque integument, which is extending backwards over the dorsal part of the head, the characteristic group of simple eyes (*d*) begins at this time to be distinctly developed, and the rudiments of the maxillary palps and of the four pairs of thoracic legs become recognizable, raised in relief upon the epimeral segments; now, also, the dorsal vessel (*f*) appears along the upper curvature of the abdomen; and thus all the chief characteristics of the future spider are manifested, whilst the great mass of the vitellus remains still visible through the transparent and incomplete lateral and dorsal parts of the integument.

The constriction between the two divisions of the body increases; the legs and palpi next present slight traces of articulations; as they increase in length they cross the middle line of the sternum and interlock with those of the opposite side. The mouth, the vent, and the wide alimentary canal are formed; the integument is completed, as in other *Articulata*, by a dorsal cicatrix, and in this state the young spider breaks through the attenuated chorion. The jaw-shaped antennæ, the cephalothorax, and abdomen, are first extricated, and afterwards, but with more difficulty, the palpi and legs are withdrawn. A similar process has soon to be repeated in the casting off the fœtal integument, which becomes too small for the rapid growth of the young spider. This first moult always takes place in the silken nest of the parent; the young spider then issues forth, and is subject to repeated moults before acquiring the mature size. We perceive, therefore, that throughout the whole process of the development of a spider, there is nothing worthy to be called a metamorphosis. The highest of the Articulata never acquires the condition of the apodal and acephalous worm; the rudiments of the head, with its eye-specks, and of the limbs, are manifested before the vitelline mass is included by the abdominal walls or intestinal membrane: the tripartite character of the insect—head, thorax, and abdomen—is faintly and briefly indicated; but, with the first indications of the ocelli, trophi, and legs, the special arachnidal form is acquired.

In certain aquatic Arachnida, *Nymphon*, *Pycnogonum*, e. g., there is such a change of proportions of the body and limbs as might deserve to be called a metamorphosis; but even these first acquire the Arachnidal type before retrograding to a lower parasitic form. Most mites have only six legs when hatched, but they otherwise resemble the adults, and after the ecdysis acquire the fourth pair of legs. The young of *Hydrachna* are likewise at first hexapod, and they have also a long and large snout, like a distinct head. With this they pierce the bodies of water-insects, and pass their first stage in a parasitic state, in which they have been called *Achlysiæ*.*

The regeneration of the legs of the spider follows precisely the same law as that which regulates their reproduction in the Crustacea. If the limb be injured at the tarsus, tibia, or femur, it must first be cast off at the coxo-femoral joint, before the process of reproduction can commence, and this must be preceded by a moulting of the integument; the new leg being at first of small size, but with all its joints and appendages, and acquiring the full proportions at the second moult. The palp, with the accessory generative organ, has been reproduced in the male, and has proved to be efficient.

Class ARACHNIDA.

Head usually confluent with thorax, and provided with modified, commonly mandibuliform, antennæ: no wings; four pairs of *legs*.

Respiratory system, when present, tracheal, or pulmonary, or both.

Order DERMOPHYSA.

No distinct respiratory organs: respiration performed by the common integument. Cephalothorax multiarticulate.

TARDIGRADA. Legs rudimentary; abdomen wanting: hermaphrodite.
Genera *Macrobiotus*, *Emydium*, *Milnesium*.

NULLIGRADA. Legs rudimentary; abdomen long and slender: hermaphrodite.
Genus *Demodex*.

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* CCXCI. p. 138. taf. 1.

EVIGRADA. Legs much developed; abdomen rudimentary: bisexual.
Genera *Pycnogonum, Nymphon, Ammothea, Pallene, Phoxichilus.*

Order TRACHEARIA.

piratory organs consisting of tracheæ. Cephalothorax one or ticulated. Bisexual.

CARINA. Abdomen unarticulated and fused with the cephalothorax. Palpi simple.
ARIDÆ. Genera *Sarcoptes, Glycyphagus, Tyroglyphus, Melichares, Acarus, Pteroptus.*
RACHNIDÆ. Genera *Limnochares, Arrenurus, Diplodontus, Hydrachna, Atax.*
IBATIDÆ. Genera *Hoplophora, Oribates, Pelops, Damæus.*
MASIDÆ. Genera *Dermanyssus, Uropoda, Gamasus, Argus.*
DIDÆ. Genus *Ixodes.*
ELLIDÆ. Genera *Bdella, Molgus.*
MBIDIDÆ. Genera *Erythræus, Trombidium, Smaridia, Tetranychus, Rhyncholophus, Penthaleus.*
LIONINA. Abdomen articulated, but indistinctly separated from the cephalothorax. Palpi simple.
Genera *Phalangium, Gonyleptes, Eusarcus.*
C. PSEUDOSCORPII. Abdomen articulated, but indistinctly separated from the cephalothorax. Palpi forficulate.
Genera *Obisium, Chelifer.*
D. SOLPUGII. Abdomen articulated, distinctly separated from the cephalothorax. Palpi simple.
Genus *Galeodes.*

Order PULMOTRACHEARIA.

Respiratory organs consisting of tracheæ and pulmonary sacs. Abdomen and cephalothorax unarticulated, distinct from each other.

NATANTES. Genus *Argyroneta.*
SEDENTES. Genera *Theridion, Episina, Linyphia, Zosis, Uloborus, Tetragnatha, Epeira, Nyssus, Agelena, Lachesis, Tegenaria.*
ERRANTES. Genera *Artema, Pholcus, Latrodictus, Clotho, Drassus, Clubiona.*
VAGANTES. Genera *Clastes, Sparassus, Philodromus, Eripus, Selenops, Thomisus, Delena.*
VENANTES. Genera *Attus, Myrmecia, Dolophenes, Sphasus, Ctenus, Dolomedes, Lycosa, Omosites, Seges-*

tria, *Uptiotes*, *Dysdera*, *Sphodros*, *Filistata*, *Oletera*, *Mygale*.

Order PULMONARIA.

Respiratory organs consisting only of pulmonary lamelligerous sacs. Cephalothorax unarticulated; abdomen articulated.

PHRYNIDÆ.	Abdomen distinct from cephalothorax. Chelicers unguiculate Genera *Phrynus*, *Theliphonus*.
SCORPIONIDÆ.	Abdomen indistinctly separated from the cephalothorax. Chelicers forficulate. Genera *Scorpio*, *Buthus*, *Androctonus*.

LECTURE XX.

TUNICATA, BRACHIOPODA.

THE Articulate series of animals leads the investigator of the ascending course of organic development from the Entozoa to the higher organised worms which circulate red blood, and through the strange and changeable forms of Epizoa and Cirripedia to the Crustacea, the Insecta, and the Arachnida, in which three highest classes of articulated animals with jointed limbs, as many diverging branches from the common vermiform root seem respectively to terminate.

Yet having attained these several summits of the articulate branch of organisation, the inquirer still finds himself at a great distance from any of the Vertebrate forms of animal life. How vast the hiatus which separates the worm from the lamprey, the crab from the tortoise, and the beetle from the bird or bat! He soon attains the conviction that there is no regular and uninterrupted ascent in the scale of organisation, as Bonnet fancied; no single progressive series of beings; no necessitated connection of such, as the Poet believed, who sang,—

> "From Nature's chain whatever link we strike,
> Tenth or ten thousandth breaks the chain alike."—*Pope*.

How strikingly illustrative of the subsequent progress of the science of animal life is this evidence of the creed of the bard of Twickenham, in which he has recorded in imperishable verse the convictions of the most cultivated minds of his day!

Not even the insight which we now command into the living forms that peopled this planet during past and remote epochs of its history, can supply all the actual hiatuses, and connect together in a linear series the existing and extinct members of the Animal Kingdom. But we can discern that many connecting links in partial series have perished; and we know that the broken hypothetical chain of Nature nevertheless continues to flourish and to adequately fulfil its appointed office in maintaining the balance of the conflicting influences of increase and decay, and the general well-being and progress of organic life upon the present surface of the earth.

If we would make a closer approach to the vertebrate type of organisation, we must retrace our steps, and, again returning to the Radiata, ascend by another and very different series of animals from those which have occupied our attention in the preceding Lectures.

In the Articulata the advance is most conspicuous in the organs peculiar to animal life, and was manifested in the powers of locomotion, and in the instincts, which are so various and wonderful in the insect class.

In the Mollusca the developmental energies seem to have been expended chiefly in the perfection of the vegetal series of organs, or those concerned in the immediate preservation of the individual and the species.

The Mollusca are so called on account of the soft unjointed nature of their external integument. The scattered centres of the nervous system, disposed according to the Heterogangliate type of that dominant system of organs, is often accompanied with an unsymmetrical form of the entire body; which, in compensation for the low condition of the perceptive energies, is protected in most of the species by one or more dense calcareous plates, called shells.

All Mollusca have a complete alimentary canal, with mouth, stomach, intestine, and vent; and they are provided with circulating and respiratory organs.

The nervous system, as has been explained in the introductory lecture, consists of a medullary collar, surrounding the œsophagus, and communicating with more or fewer ganglions near the œsophagus, or dispersed, usually below the alimentary canal, in other parts of the body.

In a large proportion of the lower organised Mollusca there is no head and no brain; no nervous centre being needed above the gullet for the reception of the impressions received by special organs of sense. The inlet for the food is simply a pharynx or beginning of the œsophagus, without jaws, tongue, or mouth properly so called. All other Mollusca are provided with a head, which generally supports feelers or soft tentacula, eyes, and a mouth armed with jaws.

The Molluscous province may thus be primarily divided into *Acephala* and *Encephala.*

The acephalous Mollusca are all aquatic, and are divided into classes according to the modifications of their integument or of their gills.

The *Tunicata* are those which are inclosed by an elastic gelatinous uncalcified integument; they breathe either by a vascular pharyngeal sac, or by a riband-shaped gill stretched across the common visceral cavity.

Hunter, who had anatomised the typical forms of this class, and had recognised the homology of their flexible case to the shells of the bivalves, to which mollusks he saw that Banks's "Dagyza" and the "Squirters" of our own shores were most nearly allied, grouped together the *Salpæ* and *Ascidiæ*, as they are now called, into a natural family, which he termed "soft-shelled;" * this family is the same as that afterwards defined and called "shell-less Acephala" by Cuvier, and *Tunicata* by Lamarck. All the other Acephala have a shell.

The *Brachiopoda* are defended by a bivalve shell, have two long spiral arms developed from the sides of the mouth, and respire by means of their vascular integument or mantle. One valve of the shell is applied to the back, the other to the belly of the animal, which is attached by its shell or a pedicle to some foreign body.

The *Lamellibranchia* are bivalve conchiferous Mollusca, which respire by gills in the form of vascular plates of membrane attached to the mantle. One valve is applied to the right side, the other to the left side, of the animal. The common oyster and mussel are examples of this best known class of Acephalous Mollusca.

The Encephalous Mollusca are divided into classes according to the modifications of the locomotive organs.

The *Pteropoda* swim by two wing-like muscular expansions extended outwards from the sides of the head.

The *Gasteropoda* creep by means of a muscular disc attached to a greater or less extent of the under part of the body.

The *Cephalopoda* have all or part of their locomotive organs attached to the head, generally in the form of muscular arms or tentacula.

In the last class only do we find, in the present series of animals, an internal skeleton, combined, in some, with a shell. In the rest of the Mollusca the hard parts, when present, are external; but the integument is sometimes uncalcified and flexible, as in the low organised class which will occupy our attention to-day, and which in this condition of their exo-skeleton afford the parallel to the cartilaginous state of the endo-skeleton in some of the lowest of the vertebrate series.

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* X. vol. i. p. 266.

To connect the Tunicata with any of the classes of animals which we have previously considered, it is necessary to revert to the Polypi, for it is in this group of the Radiata that we shall find the animals which have the closest natural alliance with the present class of Mollusca.

Suppose a Bryozoon to have its ciliated oral tentacula reduced to mere rudiments, and to have the pharynx enormously expanded, with its vascular internal surface richly beset with vibratile cilia; it would then be converted into an Ascidian, and the transition from the Radiated to the Molluscous series would be effected;—so easily, as it would seem, and at the expense of so slight a change of any essential structure, that some, according to the importance they may attach to the Zoologist's definitions, groupings, and divisions, might be disposed to blame the present entry upon the molluscous type of organisation by the class in which the respiratory organ is distinctly developed and the polype-form abandoned. It is chiefly by reason of the external character of the crown of radiating tentacles that the Bryozoa have been placed in the radiated sub-kingdom. Their minute size, fixed position, composite aggregation, and gemmiparous propagation added, doubtless, to the belief in their being Polypi. But relations of size have no value in classification; the mouse is as good a mammal as the elephant. The choice of their position mainly depends upon the importance assigned to certain phenomena of development (p. 153). According as the Naturalist calls the Flustra a polype or a mollusk, he exemplifies his mode of interpreting the signification of the difference between the ciliated gemmule of the Flustra and the cercariform larva of the Polyclinum, of the resemblance of the bristled coriaceous ovum of the fresh-water Alcyonella to that of the fresh-water Hydra, and of the difference of both from the ovum of any known compound Ascidian. If these significant indications of the fundamental affinity of the Polypes, with the retention of the polype-form, and the absence of a respiratory organ in the highest of that class should beget a doubt as to the propriety of calling a Bryozoon a Mollusk, and thereby losing the advantage of the latter term as a definite and intelligible sign of a certain advance of organisation, the comparative anatomist, whilst admitting the full amount of the affinity of the Bryozoa with the Tunicata, and thereby illustrating his view of the Molluscous series as constituting a great parallel branch of the animal kingdom with the articulate series*, may anticipate a verdict in favour of his judgment, in the necessarily artificial mode of successively treating of the different types and grades of organisation, if he should select the compound Ascidians as the point at which, for his needs of description and generalization, he severs an unequivocally natural series of animals from the wide-spread root or base from which it springs.

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* LXXXIV. p. 269.

The Bryozoa and many Tunicata, after their severally distinct modes of larval locomotive life, become rooted, like plants: some Tunicata, moreover, form groups of individuals united together by a common organised external integument; the present order of the class consists, in fact, of compound and simple Ascidians. I shall first demonstrate the organisation of this group by the larger examples of the simple or solitary Ascidians *, which do not essentially differ in anatomical structure from the compound species, whose small size renders this a subject for microscopic investigation.

TUNICATA.

The exterior tunic of the solitary Ascidian (*fig.* 178.) is a thick gelatinous or coriaceous elastic substance, adhering by its base or by a long flexible peduncle to some foreign body, and perforated at the opposite end or at the side by two apertures (*a* and *b*). The exterior of this tunic is sometimes rough and warty, the inner surface always smooth and lubricous. Microscopically examined, it consists chiefly of a conglomerate of non-nucleated cells like the parenchyma of *Cacti;* chemically analysed, 100 parts of the tissue, free from ash and water, gives of carbon 45·38, Hydrogen 6·47; being the same composition as the "cellulose" of plants.† This non-azotised tissue is traversed by large blood-vessels, and towards its inner surface crystals and nuclei are abundant in the clear homogeneous basis. The lining membrane is composed of a layer of polygonal, nucleated, epithelial cells.

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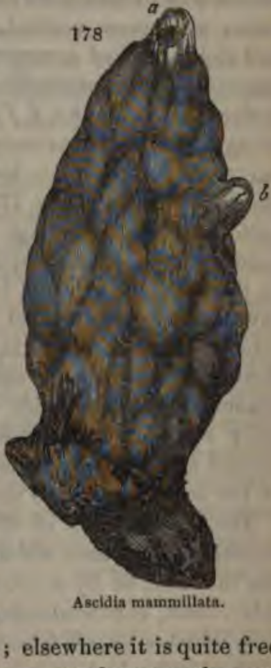

Ascidia mammillata.

The second tunic is muscular; it adheres to the outer tunic at the circumference of the two orifices, and is connected to it by blood-vessels at a few other points; elsewhere it is quite free, and the opposed surfaces of the intervening space between the muscular and elastic tunics has the aspect of a serous cavity. Its fine fasciculi of fibres are remarkably distinct, and are arranged in two layers,—the external circular, the internal longitudinal. The fibres or fasciculi of the outer layer are smaller than those of the inner one, and less regularly disposed. They describe regular circles around the processes leading to the orifices of the shell. Other fibres of the outer layer pass transversely from one tube to the other. The longitudinal fasciculi radiate from the two orifices, and decussate each other, winding round the bottom of the sac. Deeper, again, than this layer there is a sphincter surrounding the base of each tube, or orifice, from which a third more delicate layer of longitudinal fibres is given off.

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* Preps. Nos. 614, 615, 616. 785, 898 B. 998. 1303 C.

† IX. p. 34.

Of the two more or less protuberant and stellate apertures in the outer tunic, one (*b*) leads directly into the muscular sac, the other (*a*) into a wide vascular branchial sac contained in the muscular one. The entry to the branchial sac is defended by a circle of short tentacles (*fig.*179, *f*). The sac is dissected away in this figure. The inner surface of the sac is marked by parallel and equidistant transverse lines, the interspaces of which are divided into a series of narrow vertical, perforated, and richly ciliated compartments: two opposite narrow longitudinal tracts are entire (*figs.* 180, 184, *f*, *f*). A groove along that which traverses the larger curvature of the sac leads to the mouth—an orifice (*fig.* 179, *a*) at the bottom of the branchial sac, which conducts, by a short œsophageal canal, to the stomach (*b*); this is an oblong cavity, with longitudinal folds. The intestine is disposed in a sigmoid flexure, adheres to the outside of the branchial and the inside of the muscular sac, and terminates by a fimbriated anal aperture (*c*) near the base of the second orifice of the tunic (*d*).

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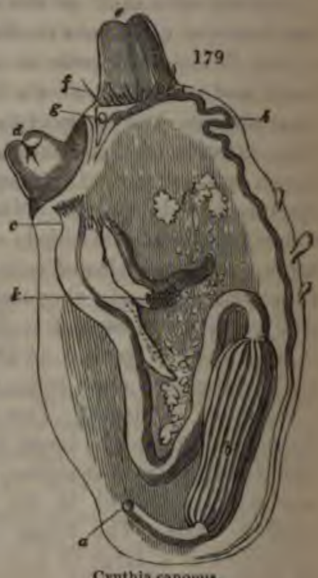

Cynthia canopus.

The liver consists of blind follicles, produced into tubes which anastomose, surrounding more or less of the intestine, as by a net-work, and ultimately, at least in *Cynthia tuberculata*, communicating with the stomach by a single aperture, from which a groove is continued towards the cardia.

The heart (*h*) is a simple, elongated, vasiform muscle, inclosed in a pericardium, attached to the branchial sac; continued at either end into a vessel; the ramifications of one being expended chiefly upon the respiratory organ; those of the other upon the tunics of the body, or speedily expanding into sinuses surrounding the viscera. According to the direction of the circulating currents the one trunk-vessel will be an artery, the other a vein, and the circulation itself will be pulmonic or systemic.

The nervous system must be first sought for in the interspace between the two openings of the muscular tunic; there you will find a ganglion (*g*), from which it is not difficult to trace filaments diverging to each aperture of the sac where the circular disposition of the muscular fibres prevails; other branches accompany the longitudinal fibres, and supply the respiratory sac; two contiguous filaments are continued to the œsophageal orifice.

Eight pigment- or eye-specks have been detected at the entrance of the respiratory tube; and six, of a deep yellow colour, at the entrance of the anal tube.

In the animal manifesting this organisation, which is much richer unquestionably than the amorphous and rugged exterior would seem to promise, the only vital actions obvious to ordinary vision are an occasional ejection of water from the orifices of the tunic by a sudden contraction, succeeded by a slow and gradual expansion. Such contractions and expansions, aided by the ciliary currents, and the peristaltic movements of the alimentary, circulating, and secerning tubes, are all the actions which the organic machinery has to perform in the living ascidian.

The respiratory currents of sea water with the nutrient molecules in suspension are introduced by the ciliary action through the branchial orifice (*e*, *fig.* 179) into the pharyngeal respiratory sac, from which the œsophagus (*a*) selects the appropriate food. The alimentary excretions and the generative products are expelled through the anal outlet (*c*) by the contraction of the muscular tunic.

In consequence of the space between this and the outer tunic being closed, that tunic accompanies the muscular tunic in its contraction, through the influence of the surrounding pressure; when the muscle ceases to act, the elasticity of the outer coat begins to restore the fibrous sac to its former capacity, and the surrounding water flows into its cavity, either directly or by distending the branchial sac. We shall find other instances of the economising of muscular force by the substitution of elasticity as we ascend in the survey of the molluscous organisation.

In the small compound Ascidians the organisation is essentially like that of the solitary species, but the viscera are somewhat differently disposed: the cavity of the body is longer and narrower, the entire animal viewed singly being more vermiform. In their natural organic association they are arranged in different modes, and under different forms; some, as the beautiful Diazona, diverging like the petals of a compound flower from a common base; others, as the Botryllus, being arranged in circles round a common central aperture, beneath which the anal extremity of the intestine of each individual terminates; whilst many of these circles of individuals are aggregated together, and enveloped in a common cellulose tunic. The substance of this is, in some species, e. g. *Leptodinum*, crowded with calcareous granules; in others, e. g. *Botryllus*, it exhibits distinct fibres.

In *fig.* 180., from Milne Edwards' elaborate memoir*, the anatomy of one of the individuals of the species which he has called *Amaroucium proliferum*, extracted from the common investing tunic, is displayed. *a* is the proper or muscular tunic, in which most of the fibres are longitudinal; it is much more feeble than in the solitary Ascidians: *c* is the oral or branchial orifice; *e*, *f*, the branchial sac; *i*, the anal or cloacal outlet; it is protected by the overhanging valve *i'*, which is required by the compound Ascidians on account of the excretory outlet in the muscular tunic communicating with a common cloacal cavity in the external tunic, around which the individuals of the composite series are grouped: *j* is the ganglion of the nervous system; *k*, the short and wide œsophagus; *l*, the stomach, the exterior of which is rendered shaggy by the appended biliary follicles; *m*, is the intestine; *n*, the anus; *o* is the heart, which, by its remoteness from the branchial sac, differs more in relative position from its homologue in the simple Ascidians than any other viscus; it is provided with a pericardium *ó*: *p* is the ovarium; *p''* an ovum about to escape through the cloacal outlet, with the embryo ripe for exclusion. The most important structural difference between the aggregate and solitary Ascidians is the combination in the former of a male apparatus with the ovarium. In *fig.* 180, *g* is the testis, and *r*, the vas deferens, which terminates at *r'*, in the common cavity of the muscular tunic. In *Botryllus* the branchial sac resembles, in its relative size and position to the intestine, that of most solitary Ascidians.

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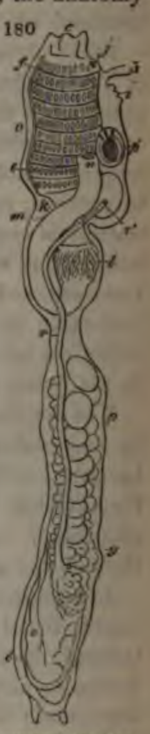

Compound Ascidian.

Some of the compound Ascidians are ramified, and their tunics so transparent as to permit the movements of the internal organs to be studied in the living animal. A very singular condition of the circulating system has thus been detected.† The blood actually moves backwards and forwards, to and from the heart in the same vessels, as it was supposed to ebb and flow in the human veins before Harvey's great discovery. The oscillation of the currents is not constant and regular ; the blood is received from the vessel at one end of the heart, and propelled by a contractile wave into the vessel at the opposite end: after a true circulation has gone on in this course for a certain period, a change is observed in the course of the peristaltic contractions of the heart; the blood for an instant stagnates in the sinuses and vessels, and then the wave travels in the opposite direction; the heart drives the blood into the vessel from which it had before received it, and the course of the circulation is reversed. In the compound Ascidians the vascular systems of the different individuals anastomose freely with each other. The veins are in the condition of large lacunar sinuses. The heart and vessels circulate blood, not water: if the vessels, as some contend, had no proper tunics (and their transparency in the living Ascidians renders them, in most of the sinuses, invisible), the sea-water which freely passes from the branchial to the muscular cavities would flow into the so-called intervisceral lacunæ, were they merely such as they seem.

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* CCXCIV.

† CVII. p. 379.

At first sight it is difficult to conceive how the fixed and compound Ascidians can multiply their race in situations at a distance from that which they themselves occupy. This difficulty has been removed by MM. Audouin and Milne Edwards, who observed that the young of the compound Ascidians were not only at their origin solitary and free, but possessed the power of swimming rapidly by the aid of the undulatory movements of a long tail. They were seen occasionally to attach themselves to the side of the vessel of sea-water containing them, and then to recommence their course, as if to seek a more suitable point of attachment. After two days of free and locomotive life, they finally fixed themselves; and, when detached, remained motionless.

These phenomena are now known to be common to the embryo of many of the lower sedentary animals. In regard to the Ascidians, it has been confirmed by Sars in the *Botrylli* of the coast of Norway *; by Sir John Graham Dalyell, in a solitary Ascidian of the Frith of Forth; and the embryogeny of the *Cynthia ampulla* has been well followed out by Prof. Van Beneden.† The solitary Ascidiæ are of distinct sex. In the male a generative gland (*fig.* 179, *k*), generally dendritic in shape, occupies the concavity of the intestinal fold, and sends a short and simple duct to terminate near the anus. In the female of the *Cynthia tuberculata* there are two ramified ovaria; the ovisacs being appended to the branches of a central stem, passing up by the side of the rectum, and extending over one side of the branchial sac.

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* CCXCVI. † CCXCVII.

In these the ova in different stages of development may be seen. In *fig.* 180., A shows the unimpregnated ovum with the germinal vessel and nucleus. In B, the impregnated germ-cell is multiplying itself at the expense of the yolk, and inclosing that by a series of secondary cells. As this process goes on, the yolk, so subdivided and assimilated, takes on a granular surface, as at C, each granule or tubercle having its hyaline nucleus. By the coalescence of the peripheral layer of these cells, an external membrane is formed, as D, on the exterior of which are oil-like globules. An albuminous fluid is now interposed between the chorion of the egg and the germ-mass. A filamentary body next begins to be formed from a part of the exterior germ-cells forming the basis of the test; which body bends over the visceral mass, E. This body or process progressively elongates, then uncoils itself, liberating the rest of the test with the visceral mass, and becoming a freely vibrating locomotive caudal appendage. In the larva, as it may now be called, F, *a* shows the anterior part of the body, *b* what is deemed a rudimental eye, *c* is the integument. In the farther advanced cercariform larva, G, the inner substance of the caudal prolongation is absorbed, leaving the cellulose sheath empty: the anterior process, *a*, is produced, and some traces of a definition of visceral parts may be detected. In H the caudal appendage is lost; the stomach and intestine are recognisable. In I the young Ascidian may be recognised as such: *a* is the branchial orifice with tentacles; *b* is the anal orifice; *c* is the eye-speck still visible, though fading; *d*, the œsophageal nervous collar; *e*, the position of a pulsating sinus; *f*, *f*, ciliated circles, which are rudiments of the respiratory bag; *g*, *g*, are muscular bands.

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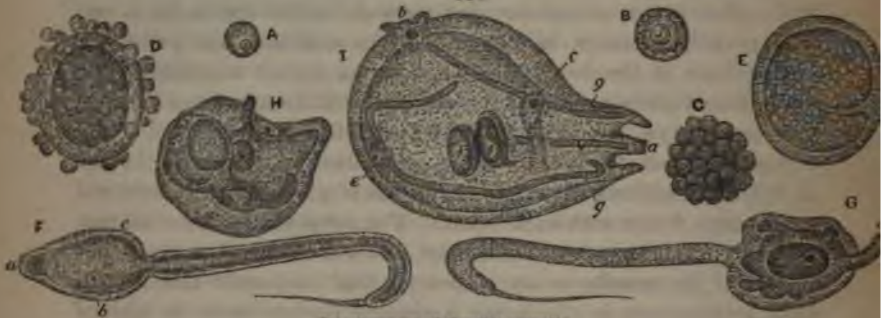

Development of Cynthia ampulla.

In the genera *Polyclinum* and *Amaroucium*, amongst the compound Ascidians, Milne Edwards has observed that the ovum, whilst still included in the ovarian mass, consists of the small central germinal vesicle, of a granular vitellus, and a vitelline membrane. In the progress of the ovum to the cloacal cavity, the yolk acquires a deep yellow colour, the germinal vesicle disappears, and in its place there is a nebulous speck upon the surface of the yolk. This is doubtless the modified germinal vesicle, which has come to the surface of the yolk to meet the impregnating influence, and has undergone the changes by fissiparous multiplication, to which I have so often had occasion to allude. Edwards has observed the contact of the spermatic animalculæ with the ova in the cloaca.

The next stage which he records is the granular or mulberry structure of the vitellus. The subdivided mass through which the properties of the hyaline and fertilising principle have been diffused, is next covered by what appears to be the expansion of the germ-spot, or a propagation from that centre of nucleated cells, closely pressed together into hexagonal forms, constituting what Herold calls the "cambium" in the spider's ovum, and forming the basis of the integument. A process of this integument then begins to extend from a particular point, and, rapidly elongating, wraps itself like a cord about the vitellus. This body, with its integument, next becomes condensed, and separates from the chord, which, retaining only its basal attachment to the pellucid integument, forms the caudal appendage. The integument (*fig.* 181, *a*) increases in thickness. The extremity of the yolk opposite the caudal attachment developes a series of cylindrical productions. Three of them have expanded extremities (*b''*, *b''*) which increase in length; whilst the other processes diminish, and finally disappear. A spiral filament is continued from the membrane of the vitellus down the centre of the tail.

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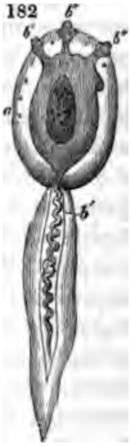

Larva of Amaroucium proliferum.

In this state the embryo escapes from the ovum, generally while in the cloaca of the parent, but sometimes after the egg has been expelled from the common central outlet. The young animal immediately unfolds its tail, and begins to swim like the tadpole of the frog, which it so much resembles in form. The three clavate cephalic processes are the organs by which Edwards believes it effects its final adhesion and settlement. When this has taken place, the tail shrinks, and is usually detached by progressively increasing contraction at its base; — a kind of spontaneous fission.

The sessile and adherent trunk now becomes the seat of an active development: the integument is thickened; the germ-mass becomes elongated and divided by a circular constriction into two unequal parts, which severally open a passage constituting, the one an oral, the other an anal, orifice. The subdivided germ-mass, which now begins to be rapidly metamorphosed into the special tissues, also acquires a distinct tunic, which soon separates itself from the thick and gelatinous external integument. The quadrifid orifice of the branchial sac is first formed upon the internal tunic. The contour of the great respiratory pharynx can next be discerned, and the constriction of the sac opposite to the mouth, which indicates the œsophagus. About the same time may be seen the outline of the anal orifice upon the internal integument; then the opaque yellow tunics of the dilated stomach, and the reflected intestine appear; and below these parts the pulsations of the large transparent vasiform heart render that organ conspicuous. Around each external orifice some mammilloid processes bud out, which first lengthen, then become lost in the thickening integument. The eye-speck continues for some little time, and is situated in the middle of the nervous collar. At the base of the abdomen the opalic concretionary body appears, to which the heart is subsequently attached, and which is provided with vibratile cilia.

The whole of the viscera included by the smooth integument have been observed to rotate in the cavity formed by the thick gelatinous tunic, to which the visceral mass again becomes attached by the adhesion of the muscular tunic at the branchial and anal orifices, and by the establishment of corresponding orifices in the integument.

Savigny was of opinion, that the ovum of the compound Ascidian contained the germs of all the individuals composing the characteristic groups in the mature aggregate animal, and that their development was simultaneous. In one sense, doubtless, the ovum contains the germs of all the future individuals developed by gemmation, in so far as a portion of the germ-mass is retained unchanged in the body of the first developed individual; but the cell-progeny of the primary germ-cell constituting that germ-mass, are not simultaneously developed: nor does any development begin until the first individual is completed, fixed, and nourished by the actions of its proper digestive apparatus. Thus stimulated and strengthened, the second mode of reproduction, namely, that by gemmation, is superinduced upon the young Ascidian, after the foregoing development from the impregnated ovum, which offers an interesting analogy to the phenomena presented by the polype-larva of the Medusa. The individuals formed by the gemmation of the primary bud of the young Ascidian, instead of being detached, are retained; the process of gemmation being regulated so as to produce the characteristic pattern in which the different individuals are grouped in the mature compound animal.

Eysenhardt[*] has observed the act of gemmation in a simple Ascidian. In this, as in the compound kinds, gemmation commences by the development of a small tubercle from the abdominal portion of the internal tunic of the young Ascidian. This is prolonged, retaining an active circulation in its interior, and is accompanied by a corresponding growth of the outer gelatinous integument, which becomes clavate. The process then bifurcates; the divisions, in like manner, becoming elongated, expanded, and bifurcated at their extremities. Soon the outline of an Ascidian is sketched in each of these extremities. The primitive connection with the parent is obliterated; but the young individuals remain united together by their common peduncle, according to the law which determines their mode of grouping into systems. By the progressive increase of their outer gelatinous integument they coalesce and form the compound mass.

The procreative force of the germ-mass finally exhausts itself in the formation of the male and female organs; in which that force is, again, mysteriously renewed, under its two forms of the spermatozoon and the germinal vesicle, by the combination of which the reproductive cycle again begins its course. On comparing this course of development with that in the Bryozoa, p. 151, I may again request attention to the genetic difference, in addition to the absence of the crown of radiating tentacles and the presence of the vascular respiratory sac, which distinguishes the compound Ascidians from the Bryozoa, and which seems to have been overlooked by those who would call the latter Mollusks. No compound Ascidian quits the ovum as a ciliated gemmule, swimming by means of groups of those vibratile organs aggregated in lobes, after the type of the *Rotifera;* and no Bryozoon, so far as I know, quits the ovum in the guise of a tadpole or cercarian, swimming by the alternate inflections of a caudal appendage.

If the term *Appendicularia* should not prove to have been applied to a caudate larve of some fixed species, that genus will permanently represent the transitional locomotive stage of the rest of the Ascidians. Its organisation does not, however, lead to the next division of the class.

A connecting link between the Ascidians and Salpians is afforded by certain compound floating gelatinous Tunicata, *e. g.* the phosphorescent *Pyrosoma*, the individuals of which are permanently aggregated into a compound organic whole having a definite form, like a flattened cylinder. The common tegumentary

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[*] CCXCVIII. p. 263. t. 36. fig. 1.

mass, of which a portion, including three individuals, is shown at A *fig.* 183, is toughish and semi-transparent. The tubercles with which its exterior is covered, consist each of one end of an individual member of the living group (*d d*); the opposite end of the individual (*b b*), opens into the cavity of the cylinder. Besides the common envelope, each individual has a distinct tunic or mantle attached at the oral or branchial orifice (*a*, B), at the anal orifice (*b*), and also to the two rounded bodies (*h*) at the upper part of the branchiæ. These (*f f*) are two in number, oval in form, with their dorsal borders in contact and attached to the mantle, and their ventral borders separated by a large sinus (*i*); their numerous vessels anastomose at right angles, and the covering tissue is beset with vibratile cilia, which perform vortex-like movements with beautiful harmony and rapidity. The œsophagus is curved, and of a bright red colour: the stomach (*d*) is subglobular, yellowish, and opake: the intestine is short, bent abruptly on itself; the anus (*b*) directed backwards towards the posterior orifice. The liver (*e*) is a globular gland, with converging segments: it is attached to the intestinal loop. These viscera are situated posterior to the branchial sac, leaving a free passage to the water which traverses that cavity. The nerve-ganglion (*j*) lies upon the anterior end of the branchial sac. The heart is placed at the posterior part of the body, below the visceral mass. In *fig.* C, *k* represents an ovum, and the part marked *g* in B, was supposed by Savigny to be an oviduct: but the precise condition of the generative organs in the Pyrosoma, is at present not clearly made out.

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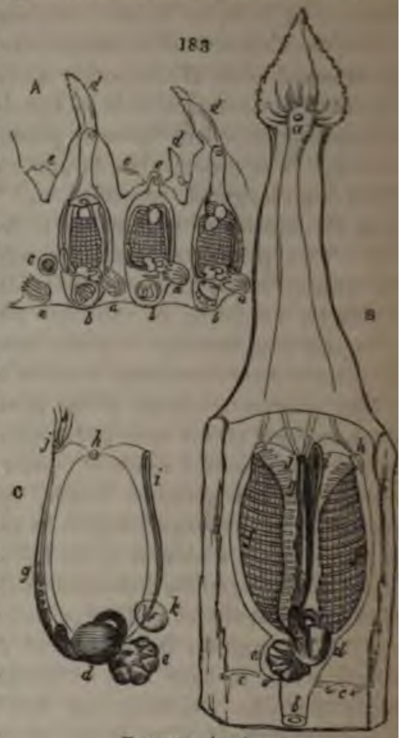

Pyrosoma giganteum.

The second order of the *Tunicata* includes the Salpians, which float in the sea, and are characterised by their transparent elastic outer tunic, which is elongated, compressed, and open at both extremities. The efferent orifice (*fig.* 184, *b*) is simple and tubular: it can be closed by a sphincter when the outer tunic expands, the water then flowing in by the opposite orifice: this is in the form of a transverse slit, having an upper lip (*a*) and a lower one (*g*): the latter forms a semilunar valve, allowing the entry and preventing the exit of water. The muscular fibres of the mantle, or membrane lining the cartilaginous tunic, are arranged in flattened, often subannular bands; their elementary fibre is plicated. The mouth and stomach, the liver and the heart, are aggregated in a small mass or 'nucleus' (*c*), near the anterior aperture of the tunic; the intestine extends towards the opposite aperture, and terminates freely in the common cavity of the mantle. The intestine in *Salpa gibbosa* has two cæca which project into the centre of the loop. In *Salpa zonaria*, the liver envelopes nearly all the intestinal canal, and consists of a mass of cæcal tubes, with a few small appendages near their free ends.* The group of small yellowish ganglia is situated just above the posterior attachment of the branchia: near it is often observed a pigment-speck or ocellus (*f*). A single narrow plicated ribband-shaped branchia (*d*) extends obliquely lengthwise across the pallial cavity. The heart (*e*) is elongated, and in some species slightly curved and sacculated; it communicates with a large vessel at each extremity, one of which is ramified principally upon the visceral mass; the other upon the branchia and the muscular tunics. The blood passes into extensive venous sinuses before returning to the heart: its course is oscillatory, as in the Ascidians.

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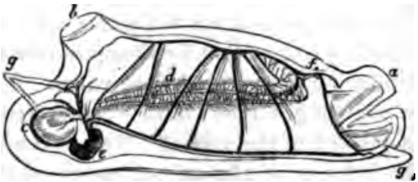

Salpa maxima.

The sexes are distinct in the Salpians, as in the solitary Ascidians. The testis is described by Krohn as of an oblong form, single, lodged in the centre of the nucleus in *Salpa maxima*, in which it consists of numerous delicate seminiferous tubes, filled with a white fluid, and opening by a short canal into the common cavity of the body. The two oblong bodies, sometimes of a violet colour, attached to the mantle at the dorsal aspect of the test, have been regarded as ovaria. Sars, however, affirms that the solitary individuals of the Salpæ are sexless. The germinative tube, in which the chain of young salpæ (*fig.* 185.) is contained, winds round the visceral nucleus, hanging freely by one end in the cavity of the mantle, and being attached by the other end to the back of the nucleus.

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* CCXCIX.

The only conspicuous vital action in the Salpians is the rhythmical contraction and expansion of the mantle; in which the elasticity of the outer tunic antagonises the muscular contraction of the inner one. During expansion, the sea-water enters by the aperture (*a*), and is expelled, in contraction, by the opposite one (*b*), its exit by the first aperture being prevented by the valve. The re-action of the jet, which is commonly forced out of a contracted tube, occasions a retrograde movement of the animal. The currents which successively traverse the interior of the animal renew the oxygenated medium upon the surface of the respiratory organ, bring the nutrient molecules within the reach of the prehensile subspiral labial membrane of the mouth, and expel the excrements and the generative products. Thus, a single act of muscular contraction is made subservient, by the admirable co-adjustment of the different organs, to the performance of the functions of locomotion, nutrition, respiration, excretion, and generation.

The aggregate Salpians quit their gemmiparous parent associated together in long chains. In *fig.* 185, *a*, *b* indicates part of the first set of young Salpæ: *c*, *d* is the second set: *e*, *f* is the third set: *g* is the stem with its germs: *h* shows the anterior orifices: *i i* are the visceral masses; *j j*, the ganglia; *k k*, the posterior orifice; *l*, the vessels; and *m*, the muscular band of the branchial sacs. After floating for a certain time, each individual, as Dr. Chamisso first discovered, propagates a young one like itself. The solitary Salpa propagated by each individual of the chain, is the product of an impregnated ovum, and is, for a time, suspended by a peduncle from the dorsal wall of the visceral cavity of the parent. In the *Salpa zonaria*, however, as many as three of such pedunculated young have been found in one parent. When liberated, the solitary Salpa grows to the size of the grand-parent, and then brings forth a social chain of young Salpæ, which, by the exercise of their uniparous generation, again give origin to the solitary and multiparous individuals. Thus, observes Chamisso, only the alternate generations resemble each other.

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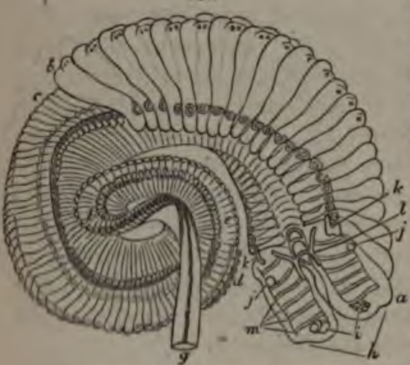

Aggregated young of Salpa zonaria.

The case is strictly analogous to the generation of the compound Ascidians, of which the solitary young gives origin, by gemmation, to a connected group, each individual of which again procreates, by impregnated ova, free individuals.

BRACHIOPODA.

The Brachiopods, like the Ascidians, are deprived of the power of locomotion, and are attached by their shell or by a peduncle to foreign bodies. Their muscular tunic or mantle is, as it were, slit open, and consists of two broad membranous expansions, called "pallial" lobes, which are covered by, and closely adhere to, two calcareous plates, adapted to enclose and defend all the soft parts of the animal. The branchial sac may be supposed to be equally cleft and adherent to the muscular one, so as to form the internal vascular layer of the pallial lobe.

The Brachiopods have left their testaceous remains in the most ancient deposits known to contain evidence of animal life: they flourished during the palæozoic and secondary periods, and are most abundant, and exemplified by the most varied forms, in the fossil state. They are now, of all Mollusks, the most widely diffused over the earth's surface, and they can exist at greater depths than most other bivalves: they are thus amongst the oldest of existing forms of animal life, and their range in time is as extensive as in space.

Of the few existing genera of this singular and beautiful order of shell-fish, the *Lingula* is characterised by its long peduncle, and by the equality of the valves of its shell, neither of which are perforated: the *Orbicula* (*Discina*, Lam.) is sessile, and adheres by one end of a short transverse muscle, which perforates the ventral valve of the shell, which is the flatter valve. The *Terebratula* (*figs.* 186 and 187) is attached by a short peduncle (*b*), which projects through a hole in a beak-shaped prolongation of the ventral valve (V), which is the more convex one. To the dorsal valve (D) is attached the internal calcareous process, usually in the form of an elastic loop, and called the apophysary system (*a*, *b*, *c*, *d*, *fig.* 187). The subdivision of the genus Terebratula*, the most characteristic of the Brachiopods, and the type of the most extensive family of the order, is based chiefly on modifications of the internal processes. The foramen in the ventral valve is usually more or less formed by a small detached part called the "deltidium." The valves are articulated by two curved

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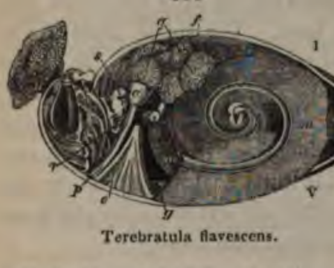

Terebratula flavescens.

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* Dim. of *terebratus*, perforated.

teeth, developed from the margin of the ventral valve, and received by sockets in the other: the joint permits only a very slight divarication of the valves.

The viscera are situated at the part of the shell next the hinge or peduncle, and are confined to a very small space in the *Terebratula*. The rest of the interspace of the lobes of the mantle is almost entirely occupied by two long fringed arms, continued from the sides of the mouth, and disposed in folds and spiral curves (*m*). The bases of the arms are confluent, and form a transverse fringed band above the mouth: a narrow parallel fold of membrane passes below the mouth (*n*), which opens upon or towards the mantle-lobe attached to the perforated valve.

In the *Terebratula australis* each arm extends outwards, advances forwards, curves slightly inwards, and bends abruptly back upon itself, the two parts of the bend being connected together; then the stem again curves forward, and becomes united to the corresponding bend of the opposite arm, the conjoined extremities describing spiral convolutions; the bent portions of the fringed arms are supported by the slender and elastic calcareous loop (*b*, *fig.* 187), which is bent back upon itself (*c*). In the *Ter. dorsata* the advancing crura of the loop, beside their basal origins, are attached by two slender transverse bars to a median ridge of the valve. In *Ter. capu serpentis* the crura are united by a slender arch, half way between their bases and the loop, which is short and not reflected. In *Thecidium* the calcareous loop is folded into two or more lobes, lying in hollows of the dorsal valve. In *Rhynchonella* the apophysary system is reduced to two short flattened and grooved lamellæ attached to the inner side of the beak of the dorsal valve. Remains of more complicated internal calcareous appendages are presented by certain extinct Brachiopods, as the *Spirifer*. In some species of existing *Terebratulæ*, as *Ter.* (*Rhynchonella*) *psittacea*, the arms are wholly disposed in a series of spiral folds, supported by only the short and simple calcareous processes at their base. The spiral arms of the *Orbiculæ* and *Lingulæ* have no internal calcareous support. In all the Brachiopods, the stem which supports the brachial fringe is hollow; and the canal is a closed cavity in each arm. In the *Terebratulæ* and *Orbiculæ* the spiral terminations of the arms have the canal surrounded by muscular fibres; the canal is filled with fluid, and, by the contraction of these fibres, the extremities are extended by the pressure of the contained fluid which is injected into them.

In most *Terebratulidæ* the [shell is traversed by minute canals from one surface to the other nearly vertically and at regular distances; their external orifices are slightly expanded. The adhesion of the mantle to the shell is due to the penetration of these pores by minute tubular processes of the external layer of the mantle*, which are covered externally by the epidermis. The free borders of the mantle-lobes are usually fringed by fine bristles, setigerous in *Terebratula*†, jointed in *Lingula.*‡

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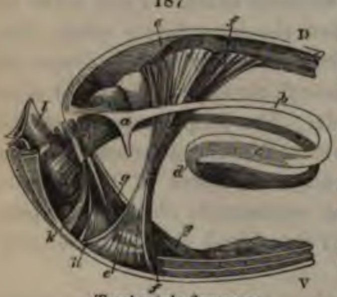

Terebratula flavescens.

The muscular system is very complex. Taking the ventral or perforated valve, to which the peduncle is directly attached, as the more fixed point, the *adductores longi* (*fig.* 187, *e*, *f*) arise from a single pyriform area at the middle of that valve, a little behind a line transversely bisecting it; the fibres soon become tendinous, converge, and group themselves into two lateral muscles forming a pair; each of these muscles, as it approaches the opposite valve, expands and subdivides into an anterior and posterior portion; glides between the stomach and the crus of the calcareous loop of its own side (*b*), and is attached by the double expanded insertion into the dorsal or perforated valve (D), the anterior division (*f*) is the "adductor longus anticus," the posterior one (*e*), "adductor longus posticus;" but both of the so-divided adductors, by reason of their ventral confluent attachment, may be regarded as constituting one quadricipital muscle. The action of this complex muscle is directly to close or adduct the valves, in which action it will slightly compress the hepatic lobes and stomach. The *adductor brevis* (*g*) forms a symmetrical pair, having their expanded disc of attachment to the ventral valve extended somewhat in advance of the confluent origin of the preceding muscles: the fibres of each pass obliquely backwards, and converge to a small round shining tendon, the tendons passing on each side the intestine to be inserted close together into the cardinal process of the dorsal valve (D). Their action will be to adduct the valves; but with a more oblique movement bearing upon the ventral valve

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* Carpenter, Report on the Microscopic Structure of Shells, Part II., Trans. Brit. Association, 1847, p. 93. "In these tubes, as will hereafter be shown, certain cœcal appendages of animal membrane are situated." — Quekett, "Histological Catalogue," vol. i. 1850, p. 270. In the same work it is shown that "each perforation has a series of radiating lines or tubes on its outer margin" (p. 270). The corresponding part of the membranous tubes would resemble a terminal brush of vibratile cilia.

† CCCI. pl. 23. fig. 13.

‡ CCCVIII. taf. i. fig. 13.

(*v*), which they, as it were, help to suspend from the hinge, as from a fixed point.

A third pair of carneo-aponeurotic muscles (*h*), which pass from valve to valve, have both extremities nearer the hinge, and, by compressing the sides of the base of the peduncle, may aid in protruding that part after it has been forcibly retracted: these "*musculi cardinales*," or hinge-muscles, are attached by their smaller and most tendinous extremity to the linear ridge between the hinge-teeth cavities and hinge plate in the imperforate valve. They arise by their larger and more fleshy ends from the imperforate valve, close together, behind the common attachment of the *adductores longi*, the rectum alone intervening; some of their fibres appear to be lost upon the sides of the sheath of the peduncle. The proper muscles of the peduncle consist of two pairs, for its retraction and attachment to the valves; and of some circular or transverse fibres of the sheath, which, though for the most part of an aponeurotic character, appear to be arranged so as to act as compressors and elongators, or protrusors, of the peduncle.

The name ***retractor inferior*** (*k*) is given to a pair of muscles which arise from the ventral valve by a thick carneous end, exterior to the "adductores longi" and "brevis:" the fibres pass obliquely backwards, and rapidly diminish to a tendon which penetrates the upper and lateral part of the sheath of the peduncle, and the terminal fibres of which appear to constitute part of the peduncle itself. This pair of muscles serves to suspend the Terebratula by means of the perforated valve to the peduncle, and forms the most direct retractor of that part, and consequently the chief agent in such limited movements, as the fettered state of the shell will allow.

The name "***retractor superior***" (*i*) is applied to a pair of muscles which have a broad subtriangular carneous origin from the hinge-plate, and a strong aponeurosis extending therefrom to the crus of the calcareous loop (*a*); the fibres curve over the sides of the swollen part of the capsule of the peduncle (*l*), penetrate the capsule, interlace with the inserted fibres of the inferior retractor, and terminate for the most part in the peduncle.

Some not very clearly defined, partly carneous, chiefly tendinous, fibres, which interlace, running mostly in the transverse direction upon and in the capsule of the peduncle, and make up, in fact, a chief part of its substance, have a transversely oblong surface of attachment or strong adhesion to the lower part of the bent conical prolongation of the ventral valve lodging the peduncle: this surface appears in the exterior of the soft parts of the Terebratula, behind the origins of the *cardinales* muscles. I have proposed the name of "*capsularis,*" for the sum of the carneo-tendinous fibres which have the attachment in question.* In conjunction with the completely encircling fibres of the peduncular capsule, they must compress and elongate the peduncle.

In addition to the muscles arranged in the more or less definite masses above described, there must be enumerated the fibres which are lodged in the walls of the canal (*fig.* 186, *m*) traversing the stems of the fringed arms; and the muscular fibres of the pallial lobes, which latter are extremely feebly developed, and recognisable only near the periphery. Thus, to recapitulate the designations of the several muscles in the *Terebratula*, as demonstrated by dissections of the *Ter. chilensis*, *Ter. psittacea*, and *Ter. flavescens*, there may be enumerated the—

Adductor longus anticus,
Adductor longus posticus,
Adductor brevis,
Cardinalis,
Retractor superior,
Retractor inferior,
Capsularis,
Brachial muscles,
Pallial muscles.

The first seven muscles leave more or less recognisable impressions on the interior of the valves: the marginal muscles of the mantle are too feebly developed to mark the shell, as it is impressed in the Lamellibranchiate bivalves.

In the Lingula the homologue of the adductor brevis is situated at the peduncular end of the shell; it is very short and thick, and passes from one valve to the other. The adductor longus posticus arises from by a common origin on one side and by two origins on the other side of the visceral mass, behind the middle of the shell. They pass obliquely to the opposite valve, the single muscle gliding between the fasciculi of the divided one.† Each adductor longus anticus arises single from the ventral valve, near the fore part of the visceral mass, and divides as it passes obliquely to the dorsal valve, the divisions decussating, but being inserted close together. The arrangements of these powerful adductors are such as to effect sliding movements of the valves on each other, besides closing the shell, and to compress and variously affect the interposed viscera and visceral lacunæ with their contained sinuses. The long pedicle of the Lingula has a stratum of muscular fibres. For the modifications of the muscular system in *Orbicula*, I may refer to my monograph on its anatomy.[*] The four adductor muscles are distinct at both ends in that genus and in *Crania*.

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* CCCIII.

† CCC. pl. vi. fig. 13.

In *Terebratula* the fringed portions of the spiral arms are not immediately supported by the loop; this serves only for the attachment of the thin but firm aponeurotic membrane which forms the true basis of support of the beautiful and peculiar organs in question.

The aponeurotic fold supporting the basis of the arms is perforated by the œsophagus, the mouth opening downwards into the pallial cavity below the beginning of the spiral fold: the alimentary canal bends backwards over the basal fold, after perforating it; the fold thus intervening between the œsophagus and intestine. The filaments given off from the beginning of the arms, supported by the basal fold are shorter than the rest. The aponeurosis, reflected from the lateral to the spiral folds, forms the fore-part of the small visceral cavity; the pallial membrane is continued from the union of the lateral with the basal folds, is stretched over the visceral interspace between the advancing crura, and is then continued backwards towards the hinge, protecting the hearts and sinuses behind the transverse fold. The lateral folds decrease in breadth as they advance forwards: the spiral fold, which, at its beginning, is broader than the broadest part of the lateral folds, gradually becomes narrower as it approaches the termination of the spire. The lamellæ of the several above-defined parts of the aponeurotic supporting and connecting brachial folds, separate when they reach the calcareous plate, and the hollow muscular stems of the fringed arms closely surround and adhere to these stems, being continued thence upon the border formed by the roots of the fringe-filaments, where the aponeurotic character is exchanged for that of a delicate membrane, which is finally lost upon the filaments themselves.

The fibres of the muscular walls of the brachial canal (*fig.* 186, *m*) are arranged in a decussating double spiral, evidently adapted for compressing the contained fluid, and thereby reacting upon the arm of which the muscular canal forms the base. In the *Terebratulidæ*, like *Rhynchonella psittacea*, with free multispiral brachia, the fluid of the canal being acted upon by the spirally-disposed muscles composing its parietes, is forcibly injected towards the extremity of the arm, which is thus unfolded and protruded outwards. In the species resembling *Ter. flavescens*, the spiral portion may also be, in like manner, so far unfolded as to react upon the closed valves of the shell.

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[*] CCCI. vol. i. p. 149.

What power the animal may possess of further unfolding and protruding the free extremity of the united spiral portions of the arms, can only be determined after careful observation of the living *Terebratulæ* in their native localities. The structure of the parts in question led me to note, in 1833, the important difference between *Lingula* and those species of *Terebratula* which resemble *Ter. chilensis* in the structure of the arms, "since, from their attachments, they are fixed and cannot be unfolded outwards as in *Lingula*."*

The muscular stem, by means of its attachment to the calcareous loop (*fig.* 187, *a*, *b*, *c*), has the power of acting upon that part to the extent its elasticity admits of, which is sufficient to produce such a degree of convexity in the reflected part of the loop, as to cause it to press upon the perforated valve, and separate it slightly from the opposite one. Observations on living Mollusks are, however, essential to the formation of adequate and exact ideas of the uses of parts of the several muscular parts of their organisation.

The fringe-filaments of the produced and reflected portions of the brachia are in a single series; they are compressed, very narrow, close set, with their flat sides towards each other, very gradually tapering to the extremity which is slightly bent, the rest of the filament being usually straight: those (*fig.* 186, *m*) of the spirally-disposed portion are split at the end, and the split is deeper as the filaments are situated nearer the end of the spire, where they appear thereby to be arranged in a double row. In most specimens the filaments of the spire incline towards each other, and meet at their extremities, inclosing a triangular space or channel. The curve of the spire is towards the dorsal valve at its commencement; and this, with the dorsal aspect of the transverse base of the arms, serves to determine the dorsal valve in *Orbicula* and *Lingula*. By Cuvier† the spiral arms of the Brachiopods are compared with the tentacles of the Cephalopods: by Siebold to those of Bryozoa (*Alcyonella*‡); perhaps the true homology lies midway: the closer connection of the soft uncalcified base of the arms to the mouth, in *Lingula*, seems transitional to the long labial tentacles of *Anomia*.

The nervous system of the Terebratula consists of three principal parts, the "pallial," "brachial," and "visceral." The roots or origins of these three systems centre in the œsophageal ring.§

This annular centre is situated in and defended by the basal fold of the brachial aponeurosis, surrounding the aperture by which the œsophagus penetrates the visceral chamber. A few very delicate filaments pass off from the part of the ring which is turned towards the aperture of the shell, and which part, from the downward bend of the mouth, is made anterior, instead of being, as in the normal position of the mouth, "dorsal." These filaments are lost in the beginning of the spiral connecting fold, the brachial arms thus receiving some of their nerves from the same part of the œsophageal ring, as the antennæ do in insects, and the cephalic tentacula in the higher Mollusks. The two chief nerve-trunks from the ring come off from its lower and lateral angles; a very slight swelling, hardly to be called a ganglion, occurring at their origin. Each of these trunks quickly divides, one division going to the mantle, the other penetrating the base of the fringed arm of its own side. The pallial trunk is the largest; it soon divides to supply the upper and lower mantle-lobes of its own side: the course of that distributed upon the dorsal lobe is shown in Plate II. *fig.* 2 of CCCIII.

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* CCCI. vol. i. p. 149.

† CCC. Mém. sur la Lingule, p. 4.

‡ XXIV. p. 260. This idea is reproduced in CCCIX. p. 117.

§ CCCIII. ζ, pl. ii. fig. 1.

The dorso-pallial nerve extends a short way upon it, and then expands into what appears to be an oblong narrow ganglion; but which is a loop formed by the slight divarication and reunion of the fibres of the trunk. From this loop most of the pallial filaments diverge. In their course towards the margin of the lobe they cross obliquely the great pallial sinus, and give off branches, most of which correspond with the branches of the sinus, these branches subdividing, and their ramifications appearing to unite in a common circumpallial nerve which runs along the inserted bases of the marginal cilia. The brachial nerves may be traced some way along the muscular canal of the fringed arms. Two delicate filaments which traverse part of the visceral chamber come off from the lower part of the œsophageal circle near the origins of the great pallio-brachial trunks; they probably supply the muscles which traverse the visceral chamber, as well as the hearts and alimentary canal. In *Lingula* the visceral nerves are more developed. They are shown in *fig.* 3, Pl. II., CCCIII. Filaments to the muscles are also more distinct: a pair, which come off from the subœsophageal ganglion, diverge as they pass backwards along the visceral chamber, then converge to their insertion in the anterior muscles; a second pair, also from the subœsophageal ganglions, run more parallel as they pass along the ventral aspect of the anterior muscles to go to the posterior muscles. *Lingula* has also the pallial and brachial systems of nerves as well developed as in *Terebratula.* I have not been able to detect any traces of special sense-organs in the Brachiopods.

The mouth (*fig.* 186, *n*) of the Terebratula is situated in the middle line, about one-third of the length of the shell from the hinge; it opens downwards, towards the ventral valve, at the base or beginning of the passage formed by the spiral brachial fold and the converging fringes of the brachial spire; it has a tumid and sub-bilobed upper or anterior lip, and a thinner and broader lower or posterior lip, which is attached to the basal portion of the fringed arms uniting the central portions. The swollen margins of the mouth are formed by both muscular fibres and secerning cells: there are no rudiments of a maxillary or dental apparatus. The organic molecules subserving the nutrition of the Brachiopods are brought by ciliary action within reach of the mouth, are there seized and swallowed. In *Orbicula* the mouth is opposite the centre of the perforated valve; in *Lingula* it is nearer the fore part of the shell. The œsophagus in *Terebratula* is short, of uniform diameter, has a delicate membranous outer tunic, a muscular coat, and a thicker epithelial lining than that of the rest of the alimentary canal. It inclines slightly forward as it ascends, between the anterior portions of the liver, to terminate in the stomach, where it is slightly constricted. The stomach (*o*) is a curved oblong cavity, swelling out slightly at the cardiac end, where it receives the biliary secretion, continuing thence for some way of the same diameter, which is rather more than half its length; and gradually contracting to the pylorus. Its tunics consist of an outer membranous, a muscular, and a smooth inner mucous coat, the epithelium of which is more delicate than in the œsophagus. The whole cavity is bent down at an acute angle with the œsophagus, and the cardiac half is buried in the large granular liver (ib. *q*). There is no valvular structure at the pylorus: but in some specimens it presented a slight circular constriction. The intestine is short, straight, and is continued downwards and a little backwards, in a line with the pyloric part of the stomach to the interspace between the attachments of the adductores longi and cardinales to the ventral valve, where the minute vent opens into the pallial cavity. It does not perforate the capsule of the pedicle. The fæces are carried out by the pallial and brachial currents.* The intestine is enveloped to within a very short distance of the vent by an extremely delicate venous sinus, the outer wall of which is connected with the plicated auricles (ib. *r*) situated on each side of the gut, a little above its middle. The muscular tunic of the intestine presents the same uniform thickness as that of the stomach. The muco-epithelial lining membranes are disposed in very delicate transverse plaits. In *Orbicula* the intestinal canal is somewhat longer, bends to the right side, where the vent opens into the pallial cavity near the right anterior adductor. In *Lingula* the intestine is still longer, forms two bends before it extends forwards to terminate at the right side, in the pallial cavity.

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* Mr. Huxley (CCCIX. p. 108) has been unable to find this vent, and describes the anal end of the intestine as imperforate. There may be blindness somewhere, but I think not at the termination of the intestine of *Terebratula*, any more than in *Orbicula* and *Lingula*.

The liver (q) is about three times the bulk of the stomach, and forms the most conspicuous of the chylopoietic viscera, when the abdominal cavity is exposed. It consists of very numerous ramified follicles, the terminal ones of which are of equal size, and their round closed ends give the apparently granular exterior surface to the gland: the intimate structure of the hepatic follicles in *Ter. flavescens* agrees with that described in my earlier Memoir*, in *Ter. psittacea* and *Ter. chilensis*. There is no natural division into lobes; a slight pressure suffices to displace groups of follicles, which then assume the lobular character. The ducts form the common stems of the manifold ramifications, and they are usually two in number, communicating, each by a distinct aperture, with the cardiac end of the stomach.

The vascular system of the Brachiopods is peculiarly well adapted to demonstrate that remarkable condition of the veins in the Molluscous class which, when first and somewhat imperfectly observed, gave rise to the idea of the blood being extravasated into the lacunæ of the viscera and the interstices of other soft parts and tissues.

Such is the condition of the major part of the vascular system in the *Terebratulæ*. The hearts are two in number, and distinct; they consist, as in other Brachiopods, each of an auricle † and a ventricle,

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* CCCI.

† This organ was first described in my Lectures of 1843 (Lecture XX., delivered May 11., published June (No. IX.) of that year), as "a small transversely plicated membranous process, continued from each side of the beginning of the intestine." In the same year, 1843, M. Vogt communicated a memoir on the Anatomy of the *Lingula anatina* to the "Allgemeinen Schweizerischen Gesellschaft," at Neuchatel, in which he described the homologous part as follows:— "Upon each heart lies a peculiar sac, unseen by Cuvier and Owen, but plainly visible in my specimens. This sac lies with its under concave smooth border upon the upper convex surface of the heart, and its free upper border is folded like a shirt-frill. The sac is depressed and hollow: at the connecting line of the folds, where this rises teat-wise (zitzenartig), there is a fissure, which leads to an extremely delicate canal, whose further continuations I could not follow; but it seemed to me that it opened externally between the two lobes of the mantle," p. 12.

No other relation of this sac to the heart is recognized, save its contiguity or contact with that organ: respecting the heart itself, M. Vogt repeats the description by Cuvier, viz. that there are two, and he expressly states that they are and are situated in the *Ter. flavescens*, at the back part of the visceral cavity, on the dorsal aspect of the intestine, one on each side of its upper or anterior half. If the dorsal valve and corresponding lobe of the mantle be removed, and the "musculi retractores superiores" be gently divaricated, or the mesial fasciculi carefully removed, the delicate membrane of the venous sinuses, continued from the margin of the basal aperture of each auricle, is immediately exposed, and is so transparent as to permit the plicated structure of those cavities to be clearly seen.* If the viscera be exposed by a side view, as in *fig.* 186, the heart (*r*, *s*) of the side exposed will be seen behind the beginning of the intestine.

The ventricle in each heart is a smooth, feebly-muscular cavity, from which are continued what have appeared to me to be arteries †; the largest ramified on the two halves of the mantle lobes nearest the ventricle, the smaller one proceeding to the viscera and muscles.

The auricular cavity consists at the half next the ventricle of a plicated muscular coat, in addition to the membranous one; but at the other half, next the venous sinuses, of venous membrane only: the latter might be termed the auricular sinus, the former the auricle proper. The proper auricle presents the form of an

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"simple, thin-coated, pyriform sacs." "Es sind einfacke dunnhautige, birnformige Säcke." Vogt subsequently ("Zoologische Briefe," 1851, vol. i. p. 285) recognised the auricular character of the part, in *Lingula*, which is so described in *Terebratula* (CCCII. 1845, p. 292).

Mr. Huxley, who erroneously, as he afterwards acknowledged, ascribed this discovery to Vogt, specifies it as "the true complex structure of the heart." (CCCIX. p. 111.)

* CCCIII. pl. iii. 1, 1.

† The best demonstration I have been able to make of the vascular system is that shown in the injected preparations 998 A and B (X. vol. ii. p. 74), and more particularly described in CCCI. (1835), p. 154. "In one of the specimens (of *Orbicula*) I succeeded in injecting the vessels of one lobe of the mantle from one of the ventricles; in this injected preparation there evidently appeared a small uninjected line (*n' fig.* 13), as in the *Terebratulæ*, accompanying each of the larger branchial veins, running along the centre of every trunk; and these lines I conclude to be branchial arteries; if they were retractile muscles of the mantle, they might be expected to have a straighter course."

If it be true that Mr. Hancock has "arrived at the conclusion that no such arteries exist" (CCCIX. p. 112) in the sense that the ramified filaments above described have no existence, I feel no doubt that renewed examination by that excellent observer will convince him of the accuracy of my descriptions and figures (CCCI. pl. 22, fig. 11, pl. 23, fig. 11.) The interpretation of the nature of the parts is another matter. Vogt adopts my original idea. He figures the homologous part (CCCVIII. tab. ii. fig. 14. *b*) as a 'blutgefass.' In all my memoirs I have called attention to the relation of the generative parts to the pallial vessels, and I have figured the ovaria as being developed from the so-called arteries, in CCCIII. pl. 2, fig. 2, 11.

oblong depressed cone, attached by its apex to the ventricle, the apex being perforated by the auriculo-ventricular aperture, and adherent by its base to the auricular sinus, which might be said to conduct into the common peritoneal cavity, since the delicate tunics of the visceral sinuses appear to take the place of a peritoneum. The auricular walls are disposed in small plaits or folds, radiating from the apex: and the longitudinal or radiating folds are puckered by transverse folds. The figures ii and iii, pl. 3, of CCCIII., which are magnified to the same degree, exemplify two of the different states in which the plicated auricles are found in different individuals, and so far exemplify the extent of dilatation and contraction of which these complex cavities are susceptible; but they have presented more extreme differences of size in other specimens, and they must possess considerable powers of altering their capacity. It is, therefore, probable, that, when the circulating fluid is accumulated in unusual quantity in the pallial and visceral sinuses, the longitudinal auricular fibres evert and expand the margins of the basal aperture to which the delicate tunic of the sinuses is attached, that the fluid is drawn by a kind of vermicular movement or peristaltic suction into the auricles, and thence propelled by successive contraction of the circular fibres into the ventricles. From the ventricles the blood may be driven through the ramifications of the pallial and visceral vessels into the more or less irregular and capacious sinuses, and so returns slowly back to the heart. The auricles are relatively smaller in *Lingula* than in *Terebratula.*

The part of the vascular system which most conspicuously presents the usual ramified form, is that which is on the inner layer of the mantle. In *Terebratula* and *Orbicula* the branches are given off from four trunks on one pallial lobe, and two trunks on the other lobe: they terminate at the periphery in a cicumpallial vessel. In *Lingula,* there are two trunks on each lobe, which are longer and their branches are more regular and parallel, and some of them terminate in blind ends. The primary external parallel branches in *Lingula Andebardi* give off a series of short loops or cæca.[*] In all a more slender body[†] accompanies the larger vessels throughout their ramifications: in all the generative cells (testes or ovaria) are developed within the pallial vessels and apparently from the more slender ramified body.[‡]

Wherever the blood is exposed in its delicate vessels and sinuses to the sea-water, a respiratory action must go on; most actively at the part where the blood is most subdivided, viz., at the ciliated

[*] CCCI. pl. 23. fig. 16.

[†] CCCI. pl. 22. fig. 11. pl. 23. fig. 11. CCCVIII. tab. ii. fig. 14 *b.*

[‡] CCCI. pl. 22. fig. 16.

border of the mantle. The larger pallial vessels, and especially those that terminate by closed ends in *Lingula*, may be regarded as generative rather than branchial vessels, *i. e.*, as being chiefly concerned in nourishing and affording pabulum to the generative cells. In *Lingula* and *Orbicula*, the pallial trunk is continued from the ventricle. The visceral chamber, in all Brachiopods, is occupied by larger and less regular venous sinuses, which seem to form a complex peritoneal cavity. The sinus which surrounds the intestinal canal, is figured in CCCIII. pl. i., *figs.* 5 & 6, 8 (*Lingula*), pl. 3, *figs.* 1, 8, (*Terebratula*): the communication of this and other visceral sinuses with the plicated auricle in *Terebratula* is accurately represented in pl. 3, *fig.* 1, of the same monograph.

The course of the circulation can only be determined by observation of the living Brachiopod: it may be subject to oscillations, as in the *Tunicata*. Whatever its course, there is no actual extravasation: I find, after the most patient scrutiny, no evidence of an escape of the blood into mere lacunæ or interspaces excavated in the tissues of other and surrounding systems; but the result of such scrutiny has been, invariably, the detection of the continuation and expansion of the proper tunic of the veins into such seeming lacunæ or interspaces. And although, in the wide clefts between the viscera and muscles in the abdominal chamber, the tunic of the sinuses is disposed like a peritoneum, seems to perform, also, the function of a peritoneum, and the contained fluid, that of peritoneal serum, in addition to their own more proper and important offices, and although an anatomist might be permitted, by such similarity of function, to call the cavities of the sinuses "intervisceral lacunæ," and the walls of the sinuses "peritoneum,"—yet, if he were guided in his nomenclature by considerations of homology instead of analogy, he would more correctly term them "abdominal venous sinuses" and "venous tunic" respectively. In either case, as a matter of fact, there is no real or essential departure from a circulation in a closed system of vessels; but only a morphological departure from the typical character of the organs of circulation,—an extreme one, it is true, but little likely to lead astray the zootomist who had been prepared for such formal modifications of the vascular system by the discoveries of Hunter, as they are manifested in his preparations, and by the descriptions and figures of such preparations, of the venous system in the classes of Insects and Crustaceans.

The absorbent system, as Cuvier truly states*, is wanting in molluscs. In the comparatively low organised order under consideration the chyle or product of digestion must transude through the intestinal tunics into the intestinal sinus*: all the fluid answering t ph, from other parts of the organisation, will be received into the rvisceral, intermuscular, and pallial sinuses, which will perform louble but closely allied functions of veins and absorbents.

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* CCCXXI. p. 300.

he streams of sea-water excited and maintained by the complex ted structure of the mantle†, will effect the requisite respiratory changes as they course over the delicately coated, branched vessels the pallial lobes; these, therefore, form the chief seat of the eathing function; but, wherever similar currents come in contact ith the vascular system, to that extent the respiratory operations ill be diffused. In CCCIII. I suggested that the minute cæcal processes continued from the mantle into the shell-tubes "might perform an excretory function and be associated in that action with the depurative respiratory office of the mantle, the probable condition of their development being the low grade of the proper branchial organisation." (p. 4.) Dr. Carpenter, believing that certain corpuscles which he has observed in the cæcal processes are blood-corpuscles, deems it not improbable "that the apparatus in question is *branchial* in its nature."‡

The generative organs present the same form in the *Terebratulæ*, *Orbiculæ*, and *Lingulæ*, and correspond with that of the pallial sinuses in which they seem to be situated. The figures 15 & 16 *r*, *r*, pl. 22, CCCI., and *fig.* 2, pl. 2, CCCIII., represent the general form and disposition of these organs in *Terebratula*. I have observed, however, a manifest difference of texture and colour in the generative organs of different individuals of *Ter. flavescens* collected at the same period. In some specimens the organs are better defined, more compact, and of a paler colour: in others the organs are broader or more diffused, and of a deeper yellow colour. On a microscopic examination of the first kind, they are found to consist of an aggregate of minute cells, closely resembling those in the half mature testes of the common oyster. I conclude, therefore, that they are the male generative organ in the *Terebratulæ*, and that the individuals of this genus are diœcious, not, as I formerly supposed, simple hermaphrodites.§ The true ova are very plainly manifested in the broader and deeper-coloured dendritic organs. They are developed, like the sperm-cells, between the mantle and the delicate tunic of the venous sinus, apparently form the accompanying branched organ, and protrude into the sinus, pushing its lining membrane inwards. The generative organs, in the male, as in the female, developed in the ventral lobe of the mantle, commence —if we may term the part next the hinge of the shell their beginning —by a loop on each side of that lobe, situated at the point of bifurcation of the two sinuses; these loops are shown in CCCIII., *fig.* 1, pl. 3, the inner layer of the mantle, with the adherent tunic of the sinus, being reflected to show the looped portions of the ovaria (12, 12). In the dorsal lobe the generative organ commences at about the same distance from the hinge, by a simple obtuse extremity, and follows, as it advances, the ramifications of the sinus in which it is lodged. There are thus four distinct ovaria or testes, two in each mantle lobe; those of the ventral lobe being doubled, or bent upon themselves, near the cardinal-attached border of the lobe. It may be presumed that the embryos developed under the influence of their suspension in the aerated and nutrient fluids of the pallial sinuses, escape, at a certain stage of that development, by dehiscence, at or near the free ciliated border of the pallial lobes. The course and phenomena of this development would form a most interesting and acceptable subject to a competent microscopical observer favourably situated for pursuing it throughout the breeding season of the *Terebratulæ*. I have observed the following stages in ova taken from the ramified pallial ovarium of a *Lingula*, preserved in spirits. CCCIII, *pl.* 1, *fig* 7, *a*, shows an impregnated ovum, in which the germinal vesicle or vesicles have disappeared, and the germ-mass has been formed, occupying the entire ovum, which has assumed an oblong form: a peripheral stratum of the derivative germ-cells was more compact and of a somewhat lighter colour than the central mass. *Ib. b*, shows the formation of a smooth membrane, probably covered by ciliated epithelium, around the germ-mass: *Ib. c* is a transverse section of such an ovum, showing its triedral figure: *Ib. d* is an ovum further advanced, with the rudiment of a peduncle: *Ib. e*, an embryo with the peduncle more produced. I could distinguish no organs in these embryos of the *Lingula*: there was no trace of shell. Thus the *Lingulæ* are provided with a peduncle before they quit the parent.

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* CCCIII. pl. 1. 2. 8. † CCCI. pl. 23. fig. 13. CCCVIII. tab. 1. fig. 13.

‡ CCCX. p. 36. § CCCI.

On comparing together the existing genera of Brachiopods we may perceive that the modifications which are traceable in their respective organisations bear relation to the different situations which they occupy in the sea.

The *Lingula*, living usually near the surface, and sometimes where it would be left exposed by the retreating tide, if it were not buried in the sand of the shore, must meet with a greater variety and abundance of animal nutriment than can be found in the deeper waters, where the *Terebratula* usually resides. Hence its powers of prehension are greater; and Cuvier suspects that it may even enjoy a species of locomotion from the superior length of its peduncle. The organisation of its mouth and stomach indicates the molecular character of its food; but its convoluted intestine shows a capacity of extracting a quantity of nutriment proportioned to its superior activity and to the greater extent of its soft parts. The more extended pallial respiratory apparatus is in exact harmony with the above conditions of structure and habits.

With regard to the *Orbicula*, and more especially the deep sea species of *Terebratula*, both the respiration and nutrition of such animals which exist beneath a pressure of from sixty to ninety fathoms of sea-water, are subjects suggestive of interesting reflections, and lead one to contemplate with less surprise the great strength and complexity of some of the minutest parts of the frame of these diminutive creatures. In the unbroken stillness which may pervade those abysses, their existence must depend upon their power of exciting a perpetual current around them, in order to dissipate the water already laden with their effete particles, and to bring within the reach of their prehensile organs the animalcules adapted for their sustenance. The actions of the *Terebratula* and *Orbicula*, from their attachment to foreign bodies, are confined to the movements of their brachial and branchial fringe cilia, and to a slight divarication and sliding motion of their protecting valves; the simplicity of their digestive apparatus, the still greater simplicity of their branchiæ, and the diminished proportion of their soft to their hard parts, are in harmony with such limited powers. The soft parts, in both genera, are, however, remarkable for the strong and unyielding manner in which they are connected together. The muscular system is much more complex than in ordinary bivalves, and is remarkable for the compactness of its fibre and the density of the glistening tendons. Here is obviously an apparatus of sufficient power to effect the requisite motions of the valves at the depth of which they may be destined to live. The *Terebratulidæ* and *Spiriferidæ* have an internal skeleton superadded to the bivalve defensive covering, by means of which additional support is afforded to the shell, a stronger defence to the viscera, and a firmer basis of attachment to the spiral arms.

Class TUNICATA.

Body unsymmetrical, with an uncalcified tegument in form of a tunic, having two openings, and lined by the mantle; oral tentacles rudimentary or absent; no foot.

Generation by gemmation alternating with impregnated ova.

Order SACCOBRANCHIATA.

Mantle united to the tunic at the two orifices; elsewhere commonly more or less detached. Branchia, a dilated vascular sac, with a tentacular orifice.

Family *Botryllidæ.*

Body fixed: tunics of many individuals fused together into a mass, in which the individuals are grouped into systems.

Genera *Sigillina, Polyclinum, Aplidium, Amaroucium, Diazona, Didemnum, Leptoclinum, Botryllus.*

Family *Clavellinæ.*

Body fixed; individuals connected by repent tubular prolongations of their common fused tunics.

Genera *Clavellina, Perophora.*

Family *Ascidiadæ.*

Body fixed: individuals gregarious or isolated.

Sessile Genera. *Ascidia, Cyathia, Dendrodoa, Chelyosoma.*

Pedunculated Genera. *Boltenia, Cystingia, Bipapillaria.*

Family *Pelonaiadæ.*

Mantle adhering extensively to tunic, which is usually buried in mud.

Genus *Pelonaia.*

Family *Pyrosomidæ.*

Body floating: tunics of many individuals fused into a cylindrical mass, in which they have a verticillate arrangement with two orifices, one at the extremity next the outside, the other at that next the inside, of the common cylinder.

Genus *Pyrosoma.*

Order TÆNIOBRANCHIATA.

Mantle adhering throughout to the tunic. Orifices without tentacles. Branchia ribband-shaped. Individuals connected, chainwise, in one generation, solitary in the next: free and floating.

Genus *Salpa.*

Class BRACHIOPODA.

Body symmetrical, with a dorso-ventral bivalve shell, lined by a ely adherent mantle of two widely separated lobes. Oral tentacl wo, long, fringed, usually more or less spirally disposed.

Family *Terebratulidæ.*

Ventral valve with a prominent notched or perforated beak, an curved hinge-teeth: dorsal valve with a depressed umbo, rdinal process between the dental sockets, and an internal calca cous, usually, looped brachial appendage. Animal attached by short pedicle or by a ventral valve.

Genera *Terebratula, Terebratulina, Waldheimia, Terebratella Magas, Bouchardia, Morrisia, Kraussia, Argiope, Thecidium Stringocephalus.*

Family *Spiriferidæ.*

Ventral valve with prominent hinge-teeth, and slightly produced and notched beak. Dorsal valve with a small cardinal process, a divided hinge-plate, and a pair of internal slender calcareous brachial appendages disposed in numerous close spiral coils, nearly filling the shell.

Genera *Spirifer, Athyris, Retzia, Uncites.*

Family *Rhynchonellidæ.*

Ventral valve with a prominent notched beak; giving passage to a peduncle: hinge-teeth supported by dental plates. Dorsal valve with a deeply divided hinge-plate; and two short, rarely spiral, internal brachial processes.

Genera *Rhynchonella, Pentamerus, Atrypa.*

Family *Orthidæ.*

Both valves with short subequal beaks; a straight and wide hinge-plate, notched in the middle. Ventral valve with prominent teeth: dorsal valve with a tooth-like cardinal process, between two curved brachial processes.

Genera *Orthis, Strophonema, Leptæna, Koninckia, Davidsonia, Calceola.*

Family *Productidæ.*

Ventral valve convex, with a slightly notched hinge line: dorsal valve concave, with a prominent cardinal process and subcentral short brachial processes.

Genera *Producta, Strophalosia, Chonetes.*

Family *Craniadæ.*

Shell hinge-less, attached by the umbo or whole breadth of the ventral valve: a short median brachial process.

Genera *Crania.*

Family *Orbiculidæ.*

Valves not articulated. Ventral valve perforated for the passage of the pedicle.

Genera *Orbicula* (*Discina,* Lam.), *Orbiculoidea, Siphonotreta.*

Family *Lingulidæ.*

Shell hinge-less, subequivalve, attached by a longish pedicle passing out between the cardinal end of the valves. Generative sinuses prominent and parallel on the inner surface of the mantle-lobes.

Genera *Lingula, Obolus.*

LECTURE XXI.

LAMELLIBRANCHIATA.

THE relation of the contained soft parts to the bivalve shell of the *Brachiopoda* is such that one valve is ventral, the other is dorsal in position. In the *Lamellibranchiata* one valve is applied to the right and the other to the left side of the animal. In the common oyster and the Anomia, which are as fixed and motionless as the Brachiopods, the two lobes of the mantle are as little united with each other, and there is as little evidence of any locomotive organ or foot. The muscles of the shell retain a certain complexity in *Anomia,* but in *Ostrea* are reduced to a single adductor.* The spiral brachia are replaced by two shorter and more simple processes, and the inferior labial fold is produced on each side to the same length, so that there is a pair of labial processes on each side of the mouth. These appendages, like the arms in *Orbicula* and *Lingula,* have no internal calcareous support, which, by being bent, could open the valves; but they are long enough, in some species of *Anomia,* to be protruded from the shell. In other Lamellibranchs the labial processes (*fig.* 188, *d*) are short, and are more glandular than muscular. Most of the present acephalous class are free and locomotive. The instrument by which they move from place to place is a single symmetrical muscular organ (*ib. b*) developed from the ventral surface of the visceral mass. The body and protecting shell (*ib. a*) is longer in proportion to its depth in these locomotive bivalves; and there are two muscles provided for closing the valves.* The superadded one (*ib. c*) is anterior to the mouth; the homologue of that which exists in the oyster being the posterior adductor (*ib. f*). In all the present class the divarication of the valves is provided for by the insertion of an elastic substance at their hinge†; and the valves are drawn together and closed by the contraction of the adductors. The bivalves with one adductor muscle are termed "monomyaries;" those with two adductors "dimyaries." The dimyary bivalves have always a foot (*fig.* 188, *b*): in its least developed condition it is subservient to the function of a gland which secretes a glutinous material analogous to silk, the filaments of which serve to attach certain bivalves, as the Pinna and the common mussel, to rocks; these filaments are termed the "byssus (*fig.* 191, *y*, *o*)." The visceral mass occupies about half the cavity of the shell next the hinge. The rest of the interspace of the pallial lobes is almost wholly occupied by the branchial laminæ (*fig.*188, *e*, *e*), which are usually four in number, of a crescentic figure, placed two on each side of the visceral mass. This is the characteristic condition of the respiratory organs in the present class of Acephalous Mollusca, and from which it derives its name.

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* Preps. Nos. 65.

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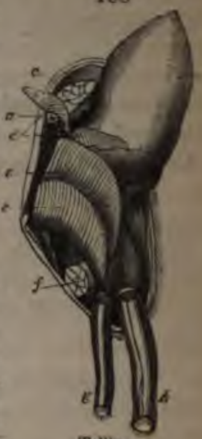

Tellina.

In the oyster the mouth opens beneath a hood-shaped fold of the mantle, at the middle of the base of the labial processes: the canal is continued by a short œsophagus to an expanded stomach, from which numerous ramified hepatic follicles are developed. The intestine, after describing a few convolutions, is continued along the branchial interspace towards the extremities of the branchiæ which are furthest from the mouth, where it opens into the pallial cavity. The ovarium or the testis surrounds the intestinal convolutions, and forms with the liver the chief part of the visceral mass.

The veins of the oyster terminate in a single auricle, which transmits the blood to a pyriform ventricle; the two divisions of the heart being contained in a distinct pericardium, situated between the visceral mass and the concave margin of the adductor muscle.

The principal centre of the nervous system lies upon the opposite convex margin of the same muscle, supplies it with nervous influence, distributes branches to the mantle, to the gills, and sends forwards two long filaments, parallel with each other, one on each side of the visceral mass, to the sides of the mouth, where they form a pair of small ganglions, communicating with each other by a transverse branch above the mouth, supplying the labial processes, and forming a second feeble communicating arch beneath the mouth, from which the gastric nerves are continued.

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* Preps. Nos. 51 and 52.

† Preps. 66, 67, X. vol. i. p. 16.

After a few examinations, guided by the foregoing sketch, of the anatomy of the most simple bivalve, the student will be prepared to comprehend and avail himself of the further details of the modifications of the Lamellibranchiate type of organisation.

In most dimyary bivalves the foot is an organ of locomotion. To some which rise to the surface of the water, it acts, by its expansion, as a float; to others it serves, by its bent form, as an instrument to drag them along the sands; to a third family it is a burrowing organ; to many it aids in the execution of short leaps. In the piddocks (*Pholas*) two strong muscles are sent from the foot to be attached to the rough spatulate terminations of the bent processes under the beaks of the valves; these serve as fulcra in the excavating actions of the foot.

We may generally observe in relation with the greater development and more active functions of the foot, a corresponding complexity of the respiratory system. This is effected by the superaddition of accessory organs in the form of tubular prolongations of certain parts of the margin of the mantle, which are provided with a special development of muscular fibres: these are called "siphons" (*ib. g, h*), and have for their retraction special muscles attached to the valves of the shell: in the *Pholas crispata* there is a third small accessory gill on each side.

In the Mediterranean bivalve called *Cytherea chione* (*fig.* 189) we have an example of one of these highest organised of the acephalous Mollusca, in which the characters of its grade of structure are instructively impressed upon the valves of the shell. The muscular fibres (*a, a*) which retract the margins of the mantle have their fixed point within the margin of the shell, and leave there a linear impression at *a' a*: the closing shell-muscles leave deeper impressions; *b* is the anterior adductor, and *b'* its corresponding impression; *c* is the posterior adductor, and *c'* its impression; *d* is the retractor of the siphons, and *d'* its impression: *e* shows the transverse fibres of the foot, which, by their contraction, lengthen the organ, and cause it to protrude: *f* marks the longitudinal fibres or retractors of the foot: their origin leaves a small roundish impression near the back part of the hinge of the shell. When the siphons are present, they are always two in number, cor-

nding with the oral and anal apertures in the tunic of the As-
: in *fig.* 189, *g* is the inhalent, and *g′* the exhalent, siphon.

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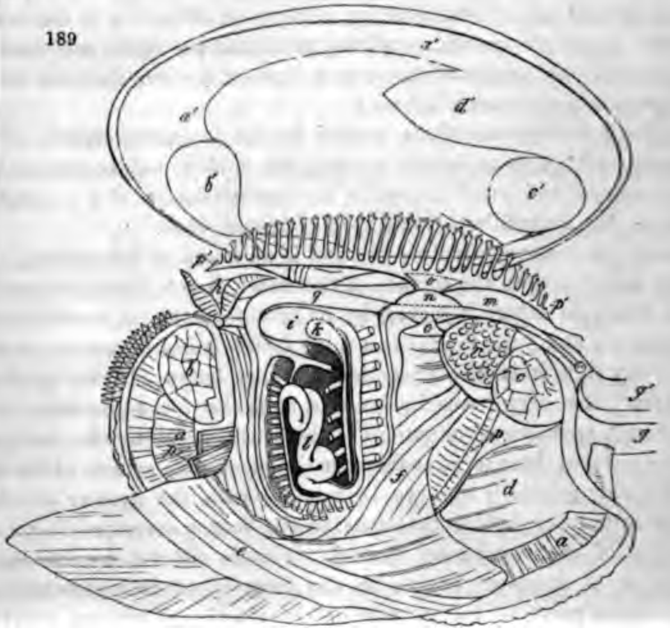

Citherea chione.

The labial processes are shown at *h*: the stomach at *i*. A remarkable elongated amber-coloured body, called the crystalline style, is indicated at *k*: it is contained in a special cyst, surrounded by circular fibres, with its free extremity protruding into the stomach. Its homologue exists in a rudimentary state "as a detached piece of cartilage" in the stomach of the Oyster; its office, as conjectured by its discoverer, being "to assist in the trituration of the food."* In the Pholas it has the form of a folded plate. To pound and mix the alimentary molecules with the gastro-hepatic secretions seems more obviously to be its function in the Bivalves, in which the style is fully developed and projects into the stomach like a pestle in a mortar.†

The intestine (*l*), after a few convolutions amongst the lobes of the liver and genital gland, forms the rectum (*m*), which perforates the ventricle of the heart (*n*), and passes dorsad of the posterior adductor to terminate by the anal opening, at the base of the siphon *g′*. The blood is received from the veins of the gills (p) in this, as in all other dimyary bivalves, by two auricles (o, o), which transmit their contents to the single fusiform ventricle, perforated in the remarkable manner just shown. In the genus *Arca*, which is remarkable for its great breadth, the ventricle itself is divided into two cavities, having the rectum in the interspace. An artery is continued from each extremity of the ventricle, which distributes the oxygenated blood over the viscera, the muscular system, and the mantle. The efferent vessels speedily lose the cylindrical form and expand or open into large sinuses conformable with the lacunæ of the viscera and other organs.

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* CCCXI. p. 17.

† X. tom. i. p. 137; preps. Nos. 404 *a*. 487, *b*.

The gills are essentially internal highly vascular folds of the pallial membrane, and are strengthened by series of delicate jointed filaments which support several rows of curved vibratile cilia. The respiratory currents are occasioned by the ceaseless action of these cilia, and are not dependent upon any opening or closing of the valves of the shell. The ciliary action is that likewise which brings the nutrient molecules to the mouth, chiefly along the marginal grooves of the branchial plates, where the molecules are mixed with mucus and moulded into small filamentary masses.

In *Lucina* and *Corbis* there is only a single gill on each side: as a general rule there are two. Each gill consists of two membranous plates, continued into each other at the free margin of the gill (*fig.* 193, *b*); the contiguous plates of the two gills are continuous at the base or bottom of the branchial interspace, where they are fixed: the basal border of the plate forming the opposite side of the gill is free where it extends along the base of the foot, and is continued into the base of the inner gill of the opposite side, behind the foot, in the fresh-water muscles, as at *e*. The two plates of each gill are united together at pretty regular intervals in the direction of their breadth by transverse septa or bars (*figs.* 190, *i*, 193, *c*) so as to include canals running transversely to the gill-plates. According to the course of the current of water through these interlaminar canals they commence by the small slits or pores along (*e*) the groove on the free margin, in the branchial chamber, and terminate by the wider openings at the fixed margin of the gill in the anal chamber.

Fig. 190 shows a magnified section of the free margin of the two gill-plates and their sustaining laminæ, showing the terminal cilia on the prominent border of each, the processes (a, a) by which contiguous bars of the same plate are joined together, and the slips or septa (i) uniting the bars of the opposite plates. The way in which the contiguous bars are united is shown at D. In the more highly magnified section, *f* shows the thick border, and *h* the thin border of at; *i* the septum, and *g* the interlaminar canal. Each blade-d bar supports three rows of cilia on each side of its base.

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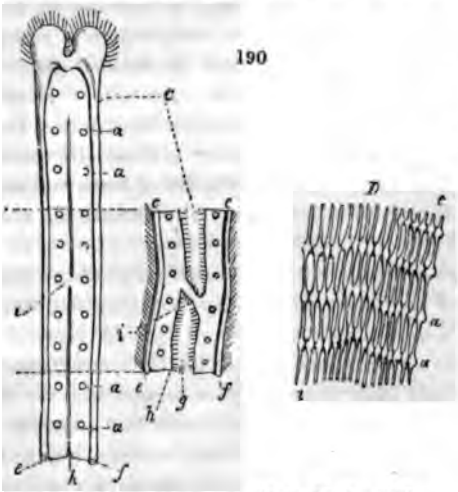

Branchial bar and cilia magnified. *Mytilus edulis.*

e minute particles suspended in the branchial currents are carried , the ciliary actions towards the mouth; and the water is filtered rough the interlaminar canals before it escapes. The walls of the nterlaminar tubes support a regular network of blood vessels, longitudinal and transverse, the latter being most prominent: the meshes are parallelograms, and form open spaces, fringed internally by a narrow ciliated membrane. The cilia compel the requisite movements of the water in the branchial chamber, when the bivalve remains suspended in the air, as happens to a mussel attached to a rock above low-water mark. Even when the animal is in such a position as to be immersed only for about two hours in seventy-five days out of the year, it can live and grow: the retained water deriving oxygen from the atmosphere, and the animalcular food propagating therein. The life of the "tree-oysters" (*Ostrea polymorpha*) suspended to the mangrove branches is similarly explained through the wonderful mechanism of the ever active microscopic cilia.

The two gills of one side are usually connected with those of the opposite side by their hind ends only; but sometimes the union is more extensive. In a few genera, as *Anatina* and *Pholadomya* the two gills of the same side are so united as to appear like a single gill. In the *Pholadomya* this forms a thick oblong mass, finely plicated transversely, attenuated at both extremities, slightly bifid at the posterior one. A line traverses longitudinally the middle of the external surface, which has no other trace of division. The branchiæ on each side adhere to the mantle by the whole of their dorsal margin, and are united together where they extend beyond the visceral mass, being separated, by the interposition of that mass, along their anterior two-thirds. A narrow groove extends along the free anterior margins of each gill. When the inner side of this apparently simple gill is examined it is seen to be divided into three longitudinal channels, by two plates, containing the vascular trunks and nerves of the gills. A style passed from the excretory siphon, behind the conjoined extremities of the branchiæ, enters the dorsal channel, from which the excretory respiratory currents are discharged; the middle channel is characterised by an orifice which conducts into the cavity of the gill, where the ova are hatched: the third channel forms the inner or mesial surface of the gill, which is not otherwise divided.

Although the microscopic cilia form the ordinary and constant dynamical part of respiration, the function is occasionally influenced by the muscles of the shell, as when the water is squirted out of the siphons by a sudden shutting of the valves. The quiet and ordinary respiratory current enters, in *Anomia*, at the anterior base of the shell, and escapes posteriorly near the termination of the branchiæ. In *Modiola vulgaris* the current enters by the cirrigerous border of mantle, and between that part and the foot: it escapes by the posterior produced part of the mantle. In *Mactra* and *Tellina*, when the conjoined siphons are extended and the hyaline valve is exserted from the anal siphon, the current flows in at the "inhalent" branchial, or ventral siphon (*fig.* 188, *h*), and rushes out by the "exhalent," dorsal, or anal siphon (*ib. g*): there is no current at the pedial aperture. The branchial siphon is often much dilated, so that its diameter greatly exceeds the anal one, *e.g.*, in *Pholas*. The siphonal apertures, especially the inhalent one, are provided with a circle of tentacles, to prevent the ingress of noxious particles.

There is a remarkable plexus at the base of the gills, near the pericardium, which surrounds a distinct glandular organ in the higher bivalves. It is double: each sac is elongated with glandular walls, and communicates with the pallial cavity by a small prominent orifice, usually close to the genital pores. The secretion of this body abounds with calcareous particles, and it was called by Poli the secreting organ of the shell: it is shown at *fig.* 189, *r*. Modern analysis has detected a large proportion of uric acid in these sacs, and has thus determined them to be the renal organ.

An orifice at the extremity of the foot of *Solen*, at the middle of the foot of *Cardium*, and the tube situated above the pedunculate anus of *Pinna*, admit the sea-water into a reticulate system of channels in the substance of the foot, thence extending into the lobes of the mantle, and into a part of the visceral mass: by this provision for the admission of water the foot can be swollen out, like a sponge, and made to exceed the capacity of the shell. The relations of this aquiferous system to the sanguiferous one, are not satisfactorily determined. The fine jets of water expelled from the foot, and the border of the mantle, when a Solen is suddenly removed from the water, are from the aquiferous canals.

The nervous system advances in a regularly proportional degree with the complexity of the general organisation, and especially with the muscular system: the ganglion upon the posterior adductor, which is most conspicuous in the oyster, is the largest and most constant in all other bivalves: it supplies the branchiæ with their nerves, and when these are approximated on each side, it is single; when they are wider apart, it is double (*b*). It is called, therefore, the branchial ganglion, but it distributes an equal share of nerves to the posterior and dorsal parts of the mantle. In the common muscle (*fig.* 191) the labial ganglions (*l*) may be distinguished by their yellow colour at the base of the labial processes. They are connected by a short transverse nervous chord (*c*), passing above or in front of the mouth. From each of the ganglions two principal nerves are given off, one (*a*) passing forwards to the anterior adductor, the other (*d*) backwards along the base of the foot and the visceral mass to the posterior adductor, where it joins the branchial ganglion (*b*). At a short distance from the labial ganglion this latter nervous chord sends off a branch (*e*), which communicates with its fellow by means of a bilobed ganglion, situated at the anterior part of the base of the foot. This pedial ganglion (*p*) and the labial and branchial ganglions constitute the principal centres of the nervous system in the *Mytilus*

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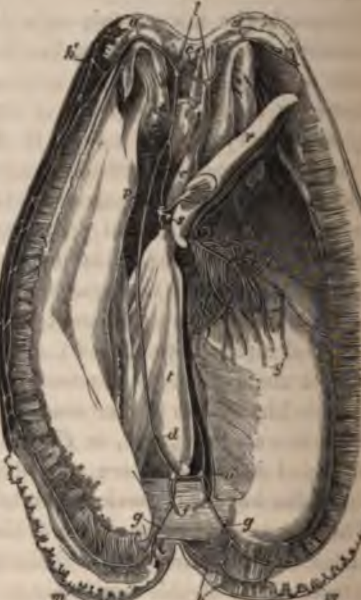

Mytilus edulis.

edulis. The pedial ganglion distributes nerves in one direction to the retractors, in another to the substance of the foot, and it sends the nerve to the acoustic sac (*s*). The branchial ganglions (*b*) send off nerves (*f*), which diverge as they pass to the base of their respective gills: then each gives off a large nerve (*g*) which passes over the adductor muscle to the hinder part of the pallial lobe, along which it curves, and is continued forwards near the border of the mantle until it meets and anastomoses with the corresponding nerve (*a*) which is continued over the anterior adductor from the labial ganglion. These circumpallial nerves (*g*, *a*) send off branches which form loops at the base of the tentacles from the posterior border of the mantle, and, along the rest of the free border, form a circumpallial plexus (*h*, *h'*), which is, also, continued along the anterior and cardinal borders of the mantle, unconformably with the circumpallial nerve.*

The nerves of this and other bivalves present the soft and pellucid structure which is so common in the aquatic invertebrata. The modification of the nervous system, in other bivalve mollusca, have been ably compared and homologised by Mr. Garner.† In the oyster the subœsophageal loop is slender and contracted, and unconnected with any other ganglion excepting the labial ones in the pedate bivalves; the subœsophageal loop is more or less lengthened, having the form of a Roman arch in the Pecten, and that of the Gothic or pointed arch in the Cardium and Mya; it has for its keystone, if we may pursue this analogy, the pedial ganglion. In some species this ganglion is more distinctly bilobed than in others; sometimes, as in the Pholas, it is situated more superficially near the tip of the foot; in all it seems to be the centre from which the viscera derive their nerves. The largest and most constant ganglions are those situated upon the posterior adductor muscle, following this muscle in all its varieties of position, and manifesting likewise differences in relation to the branchiæ, but always brought into direct communication with the oral or labial ganglions. In these bivalves, as *Ostrea*, *Cardium*, *Unio*, *Anomia*, *Venus*, *Pholas*, *Teredo*, *Solen*, *Mya*, and *Mactra*, in which the gills of one side are united to those of the opposite, the branchial ganglia are conjoined. But in those, as *Mytilus*, *Modiola*, *Pecten*, in which the branchia are separate, and at a distance from one another, the two ganglia are distinct, and joined by a transverse chord of greater or less extent. A small siphonic ganglion is developed at the point of confluence of the muscular respiratory tubes in the bivalves which possess those accessory organs of respiration.

Dr. Siebold ‡ discovered the organ of hearing in the *Cyclas Naia*, and certain *Pyrolidæ*: it consists of a small sacculus, with thick transparent walls, attached to the anterior part of the pedial ganglion, and containing a cretaceous nucleus of a crystalline structure, resoluble into four prismatic pieces, and performing remarkable oscillatory movements: this sac he regards, with much probability, as a rudimental organ of hearing. It is shown at *fig.* 191, in *Mytilus*.

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* See the beautiful dissections by Mr. Goadby, Nos. 613—619.

† CCCXIV.

‡ CCCXIII. p. 49.

The Pecten has a number of small sub-pedunculated ocelli arranged around the inner margin of the mantle; they were recognised as rudimental organs of vision, by Poli*, who, thereupon, called the Pecten *Argus*. But the name is equally merited by many other bivalves. As many as sixty ocelli have been counted on the convex side of the mantle, and ninety on the plane side, in *Spondylus gæderopus*. The Pinna has about forty brownish yellow tubercles, at the anterior part of each lobe of the mantle, near the adductor muscle. In the burrowing bivalves, with long siphons, the ocelli are aggregated, as might be anticipated, on the tentacular orifices of the breathing-tubes, usually the only parts of the animal which are exposed. In the cockles (*Cardium*) each of the numerous protractile tentacles of the short siphons bears an eye of sparkling brilliancy. The *Anomia* has about forty pallial eyes hidden amongst the marginal tentacles. In the oyster they are more numerous, of a yellowish brown colour, and situated between every second tentacle along about one-third of the mantle border.†

In the Pecten and Spondylus, the retinal expansion of the branch of the circumpallial nerve includes a vitreous body composed of non-nucleated cells, in front of which is a flattened crystalline lens: the pigmental coat consists at the back part of staff-shaped corpuscles, and in front terminates by a circular pupil. In most other bivalves the simple elements for exalting touch to a sense of light, viz., a nerve-mass and pigment mass, are alone found, without any dioptric adjuncts for the recognition of an image. Carlisle‡ first showed that oysters were sensible of light; having observed that they closed their valves when the shadow of an approaching boat was thrown forward, so as to cover them before any undulation of the water could have reached them.

The labial palps seem well adapted, both by structure and position, to exercise the sense of smell; but of the existence of this sense, or of taste, in the acephalous mollusks, we have no proof. In *Nucula* the palps are rigid. The mantle is highly susceptible of impressions by contact at its free border; and the soft, often highly coloured, ciliated processes from that and other parts of the unattached surface of the skin, especially about the inhalent and exhalent orifices, are very irritable.

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* CCCXII ii. p. 153. t. xxii., fig. 1, 4.

† XXIV. p. 261. CCCXVI.

‡ CCCXI.

Between the freely open state of the mantle in the oyster and similar monomyary bivalves (*Ostracea*), and its condition in the dimyary bivalve (*Cytherea*), selected for the demonstration of the general organisation of the Lamellibranchs, there are intermediate modifications. The common mussel is the type of a family (*Mytilacea*) in which the mantle is widely open anteriorly, the margins of the lobes being united together posteriorly, except for a small space forming an inlet for the respiratory currents and an outlet for the excrements. In the *Chamacea* the margins of the pallial lobes coalesce, leaving a small anterior aperture for the foot, a second smaller one for inhaling the respiratory and nutrient currents, and a third posterior orifice for excretion. The families typified by the *Venus* and *Mactra* have the two latter orifices produced into a siphonic tube, and the anterior or pedial aperture corresponds in width with the superior size of the foot. In the *Tellinidæ* (*fig.* 187.), the siphons are separate and can be much elongated. The modifications of the mantle are essentially the same in the family called *Inclusa*; but the narrower and longer figure of the body occasions a greater proportion of the confluent margins of the mantle between the anterior pedial and the posterior siphonic apertures, whereby the mollusk, especially when the foot is small, becomes inclosed in a membranous tube or sheath. The siphons are short and united in the razor-shell (*Solen siliqua*); they are longer and partly separate in the shorter-bodied solens. In the *Panopæa* the long common siphonic tube is covered by a thick rough epiderm and is not wholly retractile. The still longer siphon of the shipborer (*Teredo*), which forms a very great proportion of that vermiform mollusk, is unprotected by the bivalve-shell. A well-marked modification of the mantle is presented by the *Pholadomya*, which has, besides the pedial and two siphonic apertures, a fourth orifice at the under part of the base of the siphon, leading by a valvular protuberance into the anterior of the pallial cavity. This additional aperture co-exists with a second small muscular process or foot, which is bifurcate at the extremity.

The bivalve shell of the Lamellibranchs offers, as might be expected, many modifications corresponding in general with those of the mantle; but otherwise related, in a few species, with boring habits and a peculiar locality, other calcareous parts in a tubular or other form being then usually superadded. The shell consists essentially of an organised extravascular combination of gelatinous membrane and calcareous earth, chiefly carbonate of lime, arranged in successive layers, the innermost being the largest and latest formed; and each layer presenting a cellular lamellar or prismatic texture, which presents characteristic variations in different families. Each valve of the normal shell is a cone, showing every grade of depth, from the flat plate of the *Placuna*, to the produced and spiral cavity of *Isocardia* and *Diceras*; it is commonly shallow, with the *apex or umbo* turned more or less to one side and directed *forwards*. If you place a bivalve shell in the position of the *Mactra* (*fig.* 192.), *b* is the umbo, and determines *e* as the anterior border; *g*, therefore, is the posterior one, *a* the upper or dorsal, and *f* the lower or ventral border. The length of the shell is taken from *e* to *g*; its breadth, at right angles, from the dorsal to the ventral border, *f*; its thickness is measured across the closed valves, at the most prominent part, from the right to the left side of the animal. Transfer yourself, in imagination, within the shell (*fig.* 192.), with your head towards *e*, and your back towards *a* and *b*, and you will recognise the valve figured, as the *right* valve. Anterior to the umbo *b*, there is usually an oval depression, forming a concavity in the outline of the valve; it is called the *lunula c*. The hinge-ligament is sometimes between the umbones, never anterior to them. If the shell be divided by a line dropping from the umbo into an anterior (*e f*) and posterior (*f g*) part, it is never equally divided; in other words, it is inequilateral. *Pectunculus* is least so: in *Glycymeris* and *Solemya* the anterior moiety is longer than the posterior one; in almost all other bivalves it is shorter, as in *fig.* 192., and commonly much shorter. Most Lamellibranchs are *equivalve*, that is, the right and left valves are of the same size and shape. The exceptions occur in the stationary and often fixed species, which lie on one side, when the lower valve is deeper and more capacious than the upper one: this lower valve in the oyster, *Pandora*, and *Lyonsia* is the *left* valve, the smaller and flatter upper valve is the *right* one: in *Chamostrea* and *Corbula*, the left is the smallest valve. The *Placunæ*, *Pectenes*, *Spondyli*, and *Aviculidæ*

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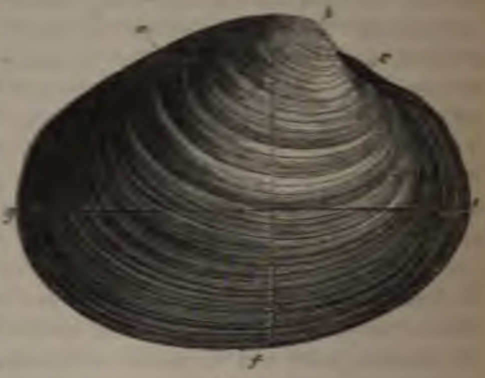

Mactra.

rest on the right valve: the *Anomiæ* are attached by degenerated muscular fibres passing through a hole or notch in that valve. All these shells are called *inequivalve*. The bivalve is called *close* when the valves fit accurately; it is *gaping* if part of the borders do not come into contact when the shell is shut: in *Gastrochæna* this permanent opening is anterior, and serves for the passage of the foot; in *Mya* it is posterior, and serves for the passage of the siphons; in *Byssoarca* it is at the ventral border, and serves for the passage of the byssus; in *Solen* and *Glycymeris* the shell gapes at both ends.

The outer surface of the shell is usually coated by an uncalcified layer of albumen called the periostracum or epiderm, continuous with the mantle. This surface is variously ornamented in many species; sometimes with ridges or "ribs," which may be either *concentric* and conformable with the layers of growth, or *radiating* from the umbones to the free margins of the valves; and the ribs may be direct, bent, oblique, or wavy. In *Tellina fabula* the sculpturing is confined to the right valve. In many species of *Pholas*, *Teredo*, and *Cardium*, the surface is divided into two areas by a dorso-ventral furrow, or by a change in the direction of the ribs. The thorny oysters (*Spondylus*), are so called on account of the spines which project from the rib-lines; they are longest and in greatest number upon the non-adhering valve. In some conditions of the shell the spines expand into foliaceous forms.

The part where the two valves are joined together is called the *hinge*. The *cardinal* or hinge-line is short in *Vulsella*, long and straight in *Avicula* and *Arca*, of moderate length and curved in most genera. The locomotive bivalves have, generally, the strongest hinges: however, a very well-developed example of the hinge mechanism may be studied in the Spondylus. Certain projections or *teeth* of one valve interlock into cavities in the opposite valve. The central teeth, usually beneath the umbo, are called *cardinal* teeth; those on each side are *lateral* teeth. In *Alasmodon* and *Kellia* only lateral teeth, in many bivalves only cardinal teeth, are present: the teeth are apt to become thickened and even obliterated by age, through irregular growth or by the encroachment of the hinge-line. Many of the fixed and boring shells are edentulous.

The soft mechanism of the hinge consists of the *ligament* and *spring*. The ligament is a tough thickened portion of albuminous matter, like that of the periostracum, and is usually attached to ridges on the outer (dorsal) part of the hinge-margin, behind the umbones; it is consequently stretched by the closing of the valves. The spring, sometimes called "internal ligament," and (though improperly) the "cartilage," is lodged in the furrows between the ligamental plates, or in pits along the hinge-line; it is composed of elastic fibres placed perpendicularly to the surfaces of attachment, so as to be compressed by the shutting of the shell, which they consequently tend to open as soon as the action of the adductors ceases. The two parts are very distinct in the bivalves thence called *Amphidesma* (double ligament); but coexist in most genera, with alternate proportions, the ligament being small in *Mactra* which has a large spring, and large in *Anodon* which has a small spring. The Pholades have the spring, but have not the ligament: this is replaced by the homologue of the anterior adductor, which is so situated as to act as an opener of the shell, and is called the "umbonal muscle." The functions of the shell in this boring bivalve are too active and too frequently in exercise to be performed by the passive elastic antagonist of the muscular closing powers which suffices for ordinary bivalves.

The formation and repair of the shell are due to the development, change of form, and calcification of cells from the mantle, its whole outer surface being the matrix of the nacreous layer, its thick and periodically glandular margin that of the opake outer portion.

The microscopic structure of bivalve and univalve shells has been well illustrated by Profs. Carpenter* and Quekett†. The primitive nucleated condition of the cell is sometimes retained after calcification.‡ The dissolved lime-salts, after endosmotic penetration of the organic walls of the modelling cell, obey so far the general crystallising force as to polarise light. The forms of the constituent lime-particles of the shell, so moulded by combined vital and polarising forces, are manifold in the various genera of bivalves. The shell of the Pinna, save a thin internal layer, is composed of vertical, slender, usually hexagonal prisms. A thin outer layer of the shell of the oyster also presents the prismatic cellular tissue; but in a great proportion of this shell nearly all trace of development from cells is lost: the gelatinous basis is lamelliform, and this variety is called the subnacreous shell-substance.

Fine tubes, analogous to those of dentine, permeate the thickness of this substance in many shells; radiating vertically between the ribs in *Arca;* vertical and scattered in the inner layer, and reticulate in the outer foliaceous spines, of the shell of *Chama*, which has an intermediate layer of ill-defined vertical prisms. The prismatic structure is rarely found, and then only in a small proportion, in the bivalves which have the mantle lobes in any degree united.

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* CCCX. † CCCXXXI. ‡ *Ib.* p. 270., fig. 157.

The distinction between the internal or nacreous layers, and the external or fibrous layers, has long been recognised, and has been forced, as it were, upon the notice of the palæontologist by the circumstance of the two being often separated from each other in fossil shells, and sometimes from one having perished whilst the other remained. As the nacreous layer alone forms the characteristic hinge uniting the two valves of the shell, and alone receives the impressions of the soft parts, the true characters of fossil shells, as those of the *Aviculidæ* and *Radiolites*, which, in consequence of their position in porous chalky beds, have lost all the nacreous layer, cease to be determinable, save when a natural mould of the interior has been formed before the pearly lining of the shell was dissolved. When the inner layer is preserved, its impressions reveal the organisation of the ancient fabricator of the shell as clearly as do the forms and processes of fossil bones that of the extinct vetebrate animal. The layers of the thick subnacreous inner substance of the shell of the *Spondylus* have frequently wide interspaces, called from their contents "water chambers:" this "camerated" structure is well shown in the right or lower valve of *Sp. varius.*[*]

The siphon in some of the elongated *Inclusa* cannot be retracted into the shell; they are consequently exposed, as in *Pholadomya* and *Pholas:* such species derive extrinsic shelter by burrowing in sand or stone. The Pholades have supplemental calcareous pieces in the hinge of the shell. Two small plates protect the umbonal muscles, and a long narrow plate fills up the dorsal interspace of the valves. The *Clavagellæ* and *Aspergilla* line their burrows with a calcareous layer, which forms in the latter a distinct tube, closed at the larger extremity by a perforated calcareous plate. One of the valves of the normal shell adheres to the tube in the *Clavagella*, and both are cemented to its inner surface in the *Aspergillum.* In the *Teredo navalis* the valves are reduced to mere appendages of the foot, at one extremity of the animal, and are almost restricted in their function to the operation of boring. As the ship-worm advances in the wood it lines its burrow with a thin layer of calcareous matter. The length of the body is chiefly due to the prolongation of the respiratory tubes, each of which is provided with a small elongated calcareous triangular paddle-shaped plate. In the *Teredo gigantea* the tube, which sometimes surpasses six feet in length, has parietes of from four to six lines in thickness, the texture of which is crystalline or spathose. Two tubes are developed within its siphonal end. In *Teredo norvegica* the tube is divided longitudinally, and also transversely, into compartments by irregular placed, incomplete, concave septa.

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[*] CCCXVIII. p. 407.

The valuable pearls of commerce are a more compact and fin kind of nacre, often developed in the substance of the mantle, around a particle of sand or other foreign body which has gain admission to the pallial cavity. The *Meleagrina* or *Avicula ma garitifera* of the Indian seas is most famous for these production Those developed in the gills or inner layer of the mantle are sma and numerous; those of the outer layer are the largest, but lea regular, and attached to the shell.

The "external" pearls consist of concentric layers of minut vertical prisms, the "internal" pearls of concentric layers of wav calcified membrane. The iridescent nacreous lining of the pear oysters (*Avicula*), and many other shells, consists of the same wav lamelliform tissue: the pearly lustre is due to the diffraction of th rays of light by the out-cropping edges of the laminæ, and, in som cases, to the minute plication of a single lamina.

If the shell of a living pearl-oyster be perforated, and a minut particle of sand introduced, it becomes a nucleus round which a pear is developed. Linnæus was knighted on making known to hi sovereign this practical application of his science; but the artificia production of pearls had long been known to the Chinese, wh obtain them of definite forms by introducing substances of the required shape into the shell.

The *Unio margaritifera*, or pearl-mussel of British lakes and rivers is fished up for the ornamental excretions to which it is subject. It i probable that the pearls from this source, collected by the ancient Britons, may have given rise to the statement by Tacitus in his Life of Agricola, of "pearls not very orient, but pale and wan," being among the indigenous products of the conquered island.*

The peculiar shape and development of the foot in the Solen and other "burrowing" bivalves might have led to its recognition as the excavating agent, if even it had not been seen to effect the purpose in the living mollusk. Direct observation of the "boring" bivalves in the act of perforation has been rarely enjoyed, and the instruments have been guessed at or judged of from the structure of the animal.

The peculiar shape, great strength, and restricted size of the concentrically ridged valves in the *Teredo navalis*, the disproportionate size and strength and the red colour of their adductor muscle, with the curved umbonal processes for its advantageous leverage, could not fail to attract the attention of the unbiassed observer to their adaptation for the function of excavating wood. It indicates a mind unfitted for physiological discovery to deny this adaptation, because the exterior of the valves be sometimes coated by a dried layer of the abundant mucus which is exuded from the pedial aperture during the active movements of the borer. The rasp-like exterior of the shell of the *Pholas crispata*, with the modifications of the adductors and their fulcral apophyses, in like manner, suggests the rasping rotatory action by which the valves may produce or aid in producing the burrows in the rocks in which the piddocks conceal themselves. To deny this use of the Pholas-shell, because the shell of some other rock-boring bivalves is smooth, is a another sign of a narrow mind. There are, doubtless, other modes of boring besides the shell-action; but the recognition of any such need not involve a negation of every mode but the one so recognised.

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* CCCXIX. p. 164.

Mr. Osler* has advocated the hypothesis of a chemical solvent as the boring agent; but such solvent has not been demonstrated; and the necessity of its being applied in currents of water to such calcareous rocks on which it could alone operate, with the liability of the shell of the animal secreting the solvent to be affected thereby, have been insuperable obstacles to the acceptance of the hypothesis.

Mr. Garner † has called attention to the ciliary currents generated by the extensive surface of ciliated epithelium in the lamellibranchs as probable aids to the rasping action of the valves: and since this demonstrated and constantly acting dynamic causes as unceasing a current of water in the holes of the borers, the non-extension of such current between the shell and the rock, where they may be in close contact, is no argument against the influence of the current in the rest of the hole, and especially at the line where it is opposed by such contact. The ingenious idea of the ciliary action as an accessory power in boring may, therefore, be accepted, from its universal applicability, and is certainly worthy of notice.

More than twenty years ago I suggested the same kind of instrument as applied to boring in rock, which had been recognised as the one used for burrowing in sand. The anatomy of the Clavagella ‡ offered many points highly suggestive of the inadequacy of the hypotheses of the burrowing-agents promulgated at the time when I first had the opportunity of dissecting that lithodomous bivalve; and its structure indicated a power that had not been previously suspected in rock-borers. In the first place, it was evident that the valves could not act, as they do in *Teredo* and *Pholas;* for the terminal expansion of the chamber had an irregular elliptical form in transverse section; and, moreover, one valve was fixed, so as to form the lining-plate of its side of the chamber. The animal I dissected (*Clavagella lata*) had formed its chamber in a rock of calcareous grit; but a nearly allied species (*Clav. australis*) had bored its way into siliceous grit; whilst specimens of *Clav. melitensis* were ensconced in argillaceous tufa. A special solvent for each species greatly complicates the chemical hypothesis. The mantle of the *Clavagella* presented, however, a peculiar modification, being expanded into a thick convex cushion where it was applied to the bottom of the chamber, through the development in its substance of a mass of interlaced muscular fibres. The last-excavated part of the chamber was, as it were, moulded to the surface of the cushion, which was perforated by a minute slit for the occasional passage of a filamentary foot. I suggested, therefore, this muscular development of the mantle as being "one of the principal instruments in the work of excavation."* But, viewing its attachment to the moveable valve, and the strength of the adductor muscles, I supposed that that valve might be applied, not only to effect the forcible expulsion of the fluid from the pallial cavity, but also, "probably, to assist in the excavation of the abode." Mr. Hancock † has recalled attention to the excavating agency of soft and muscular masses in other boring bivalves, analogous to that in *Clavagella*, as, *e.g.*, the thickened portion of the mantle in *Saxicava* and *Gastrochæna*, and the foot in *Pholas* and *Teredo*.

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* CCCXVII. p. 270.

† CCCXIV.

‡ CCCXX. p. 269.

If siliceous particles be actually secreted in the superficies of any of the burrowing discs, they must add to their efficiency: and it is certain that the perpetual renewal of a softer surface will render it capable of wearing away a harder one, subject to the friction of such softer surface, and not, like it, susceptible of being repaired.

The admission of the wearing and boring power of muscular discs need not, however, involve the rejection of the allied action of shelly valves and ciliary currents. The diversity of the organisation of the boring mollusks plainly speaks against any one single and uniform boring-agent in all.

The action of the foot and thickened border of the pedial aperture, may be inferior to that of the valves in *Teredo*, as it certainly is in *Pholas*. A valued correspondent, Mr. Robertson, of Brighton, writes, "Between thirty and forty *Pholades* have been at work in lumps of chalk, in a finger-glass and a pan of sea-water at my window for the last three months. The *Pholas dactylus* makes its hole by grating the chalk with its rasp-like valves, licking it up when pulverised with its foot, forcing it through its principal siphon, and squirting it out in oblong nodules. They turn from side to side, never going more than half-round, in their hole, and cease to work as soon as the hole is deep enough to shelter them." The Pholades attain their largest size in soft yielding stone; whilst in hard, and especially gritty rocks, they are dwarfed in size, and the rough surface of their shell is worn away. M. Caillaud has shown that the valves are quite equal to the work of boring in limestone, by imitating the natural conditions as nearly as possible, and making such a hole with them.*

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* CCCXX. p. 271.

† CCCXXII.

In *Lithodomus*, *Saxicava*, and *Ungulina*, the valves are smooth, and retain the periostracum; yet they bore into the hardest marble, and still harder shells: their holes, like that of *Clavagella*, are not cylindrical, and are doubtless formed, as in that genus, by the agency of the thickened muscular borders of the pedial aperture.

Teredo navalis bores in the direction of the grain, unless it meets another Teredo, or a knot in the timber: they are probably warned by their organ of hearing of such contiguity. The rasp-dust is introduced by the foot into the pallial cavity, and is swallowed: the long intestine of the ship-worm is usually laden with this debris. The piles of the dikes in Holland received so much damage from the ravages of the Teredo, in 1731–2, as to occasion serious alarm of a destructive inundation of the country, as the consequence of the operations of this seemingly feeble vermiform mollusk.

Generation of Lamellibranchs. — So far as actual experience extends, parthenogenesis is arrested in the molluscous province at the Tunicated class. The Lamellibranchs propagate exclusively by impregnated ova; the individuals from which, after undergoing more or less metamorphosis, exhaust the remnant of their developmental force by completing the male or the female organs. Here, therefore, there is no alternation of generative modes, save in so far as the sexless state of the twin glochidium (*fig.* 194., C) intervenes between the impregnated ovum and the perfect male or female bivalves.

The sexual organs of the higher Acephala, although as a general rule developed separately on distinct individuals, present a very simple and low character. Enormous in bulk, they ramify over the mantle in some footless Lamellibranchs (*Anomia*, *e. g.*), as in the Brachiopods, whilst the sperm-cells or the ova are aggregated at the base and interior of the foot in those bivalves which have that appendage.

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* CCCVII. p. 327.

The latest and best observations of naturalists and physiologists on the sexual characters and generation of the Lamellibranchs have established the correctness of Leuwenhoek's original conclusion * that these mollusks are of distinct sexes, some individuals being male and others female. In the small species of *Anomia* parasitic upon fuci on the south coast of England, I have found the males and females nearly equal in number, the males being distinguished by their opaque white testis abounding in spermatozoa, the females by their yellow or orange-coloured ovarium.

Milne Edwards † has pointed out two substances, of different colours, occupying the abdominal mass in the Pecten. The part to which he restricts the term ovarium occupies the inferior and posterior region of the mass; and sends a duct which traverses a portion of the different-coloured body situated above, and ascends to terminate between the bases of the labial tentacles, the summit of the abdomen, and the anterior ends of the gills. To the opaque whitish mass occupying the upper and larger half of the abdominal mass he gives the name of testis: it is composed of small vesicles grouped in bunches; its duct is continued into the foot, and terminates by two small orifices opening upon the inferior fissure of that organ.‡ These Siebold suspects may be the orifices of the secreting glands of the byssus, and Edwards has perhaps mistaken the gland and duct of the byssus, with part of the undeveloped ovary, for the testis. He did not apply the only true test of the nature of the uncoloured part, viz. the microscopical examination of its contents.

Krohn § has dissected a so proved hermaphrodite Clavagella: he found the testis beneath the liver, while the ovary surrounded it and the stomach: this appears to be an exceptional condition in the class, though perhaps constant in that peculiarly domiciled genus.

In the male Lamellibranchs the testes are double, and have a somewhat more circumscribed form than the ovaria, but sometimes appear to be blended together at the median line. In the oyster they are situated on each side of the liver, and extend in the form of a triangular process between the adductor muscle and the gills. The testes extend at the breeding season in certain genera, as *Anomia*, *Hiatella*, *Mytilus*, and *Modiola*, into the substance of the lobes of the mantle; but in those bivalves which have a large foot, the testes are confined to the base of that organ. The ultimate texture of the testes is a congeries of vesicles containing a milky fluid, which seems to consist almost wholly of spermatozoa in the breeding season. The vasa deferentia are short and wide, and they open behind the mouth in the oyster, and terminate upon papillæ at the posterior part of the foot in most dimyary mollusks, as *Cardium*, *Pholas*, *Venus*, &c.

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* XXXIX. p. 16.

† CCCXXV. pl. 10. fig. 1. p. 322.

‡ XXIV. p. 289.

§ CCCXXIII. p. 52.

The ovaria have a similar form and position in the female bivalves, but are usually more extensively ramified. The short oviduct and sperm-duct are both strongly ciliated, and open on each side at the base of the foot or visceral mass, by a narrow fissure with tumid borders, either very close to the opening of the kidneys into the mantle-cavity or in the urinary sac itself. At all seasons of the year some ova may be discerned in the ovarian cells, characterised by the germinal vesicle and spot. Towards the breeding season they are developed in immense numbers; and the addition of the coloured vitellus to the essential part of the ovum gives the characteristic colour to the ovaria. They are generally distended with the ova in the winter months. It is by virtue of the currents produced by the action of the vibratile cilia of the mantle and gills that impregnation is effected in the separate sexes of bivalves, and especially of those that, like the oyster, are fettered, male as well as female, to the rocks; just as the pollen of the rooted male of the diœcious palm is wafted by currents of air to the moist stigma of the equally fixed and rooted female tree. The fertilising filaments retain their influence after being discharged from the males, are drawn in with the respiratory currents, and at the breeding season the ovaries and oviducts contain a milky fluid abounding with the moving filaments. The ova then escape by the short oviducts, which terminate in positions analogous to those of the vasa deferentia.

The ova have usually a spherical, rarely a pyriform or elliptical, figure: the yolk (*fig.* 194, A *b*), when mature, varies from a yellow to a reddish hue; it is inclosed by a smooth vitelline membrane, and this by a thin chorion. The (often overlooked) germinal vesicle (*a*) has usually two co-attached nuclei. The small amount of albumen (*c*) which lies between the yolk-membrane and the chorion becomes more conspicuous after impregnation.

The ova do not escape when excluded from the oviduct, because during that act the shell is kept forcibly closed; and so they slip back into the gill-channels. In the *Naiadæ* the two external gills are developed into uteri or marsupial pouches for the ova, which cleave loosely together in the compartments of those gills; and in the fresh-water genus *Unio* they are excluded by the anal fissure, near to which they form oval discoid masses, in which may be recognized the

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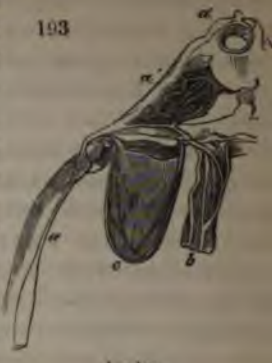

Anodon.

form of the branchial compartments. In *fig.* 193. is shown a transverse section of the right lobe of the mantle (*a*) and of the right pair of gills in a fresh-water muscle (*Anodon*), at the period when the external gill is performing its marsupial function, and is laden with the ova: *b* is the inner gill, *c* the outer gill, showing the basal canal and the free margins of the partitions of the branchial cells in which the ova are incubated.

One feels surprised at first that the ova should pass into the outer gills, when the inner ones are nearer the two sexual orifices. V. Baer pointed out the roundabout way in which the ova glide along the basis of the inner gill as far as the cloaca, and from thence through a particular canal of the mantle into the compartment of the external gill: and the same acute observer has explained how in like manner, in *Tellina*, the semen ejected from the anal tube enters by the ventral respiratory tube into the branchial chamber of the female, and passes thence into the receptacles for the ova formed by the gills.

The external gills swell out to such a size in the fresh-water mussel, *Anodon*, as to require a particular space in the shell for their lodgment, and the valves of the female are consequently more convex than those of the male. The same sexual character of the shells is observable in the genus *Unio*, and the whole family of the *Naiadæ*, as Kirtland and Lea have remarked in their beautiful monographs on the North American species of these fresh-water bivalves.*

The actual penetration of the ovum by the spermatozoon, first observed by the keen-eyed and accurate Martin Barry, who demonstrated the capital fact to me in the year 1843, has, amongst other confirmations, received satisfactory ones from Keber's and Webb's observations of the mode of impregnation of the ova of the river-mussel (*Anodon*); and from those by Lovén on *Cardium pygmæum*.† A tubular orifice, analogous to the micropyle in the vegetable ovum, is formed in or from the chorion: the spermatozoa penetrate by this temporary orifice, which then closes, and is indicated by a clear spot with a corrugated border. The spermatozoon penetrates the yolk, and there, according to Barry, divides into many parts.‡

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* CCCXXVI. † CCCXXIV. ‡ CCCXXIV. *a.*

In all the bivalves hitherto observed the yolk is a germ-yolk only, and is divided concurrently with each spontaneous fission of the contained impregnated germ-cell. Two superficial cells, alone, seem not to participate in this process, but, after the formation of the germ-mass, are changed into triangular discs, the rudiments of shells: the rest of the surface developes a ciliated epithelium, by which the embryo rotates in the ovum. In *Mytilidæ* a swimming disc is next developed, fringed with long cilia, and an exploratory filament is developed in association with the increased locomotive power.

In *Anodon* the embryonic mass soon divides itself, but not quite completely, into two halves*, each half being supported by its own valve. It looks like an attempt at spontaneous fission,—some lingering manifestations of parthenogenetic force. In fact, each of these embryonal moieties has its own mouth, which is situated near the hinge, beset with cilia, and its own intestine: on the inner sides of the cleft, at the angle which the two embryonal moieties form at the future hinge of the shell, there rises, on each side of the adductor-muscle, a hollow byssiphorous organ, from which two transparent byssus-filaments proceed. The inner surface of each moiety is also beset with three tentacle-like stiff points, with their base surrounded by a thick border. Near the hinge there passes the broad adductor-muscle above mentioned from one embryonal half to the other, which, after the young bivalve has quitted the egg, manifests its contractile force by closing the valves; these have now become slightly concave, but continue triangular in shape. Each embryonal moiety has, likewise, at first, its own distinct though simple heart; and it is by the approximation and ultimate fusion of the two ventricles that the common rectum of the originally distinct intestines is intercepted. The rest of the canal blends with its fellow as the visceral mass grows up from the bottom of the cleft, chiefly by the progressive increase of the testis or ovarium†; and thus two sexless individuals combine to form one with sexual organs.

M. de Blainville‡ denied the passage of the ova of the Lamellibranchs into the gills, and maintained their direct exclusion from the shell; on the faith of which assertion Jacobson§ was led to suppose the odd-shaped embryos in the branchial marsupium to be parasites, as the elder Rathké‖ had long previously described them to be. But, whilst many true and singular parasites have been detected and described in the Lamellibranchs, the real nature of the *Glochidium* of Rathké has been well traced out: the

* CCCXXXIII.

† CCCXXXIV. p. 312.

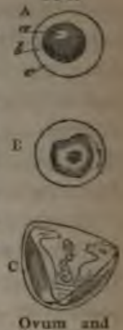
‡ CCCXXVII. p. 137.

§ CCCXXIX. p. 22.

‖ CCCXXVIII. p. 166. t. x. fig. 3.

young Anodons, so denominated, quit their marsupium usually late in September, after an intrabranchial development of two or three months. The young animal, when excluded, uses the prehensile or adhesive filament, to anchor itself to the shell of the parent or to some foreign body.

194.



Ovum and Embryo: A B, Unio; C, Anodon.

Prof. Carus* has ably traced out the course of development of *Unio litoralis*. *Fig.* 194, A, shows the unimpregnated ovarian ovum. Before the ovum has reached the branchial marsupium, the germ-mass has been formed, and some pentagonal and hexagonal cells are developed at its periphery, supporting vibratile cilia. The quantity of albumen has increased. At first movements may be observed in that part of the albumen, which is contiguous to those superficial ciliated cells. As these extend over the germ-mass the currents of albumen increase in strength, and, finally, the yolk itself begins to revolve in the surrounding fluid in the direction marked by the arrow in B. This singular phenomenon was first observed by Leuwenhoek in 1695. The embryos have now penetrated the gill. Two parallel fissures next make their appearance, which, sinking deeper into the germ-mass, divide that part into two, and mark out at the bottom the rudiment of the visceral mass, which is subsequently to rise between the lobes of the mantle. Calcification commences on the outer surface of these lobes, and the first layer of the future shell forms a small triangular valve on each side.

When the rotation of the embryo is most active, seven or eight revolutions may be observed in the minute. The gills make their appearance as ciliated wavy folds from the inner surface of the mantle, near the angle between the pallial lobes and the visceral mass. The development of the adductor muscle, single at the beginning and near the hinge, is indicated by feeble attempts at opening and closing the valves. The albumen during this development is absorbed and assimilated, and the embryo now distends the chorion. In the young *Anodon* (*fig.* 194, C), long filamentary processes twisted together like a byssus, are developed from the visceral mass: the thick short fleshy foot is subsequently developed in place of the byssiform filaments. Both the young *Uniones* and *Anodontes* escape from the chorion before they quit the marsupium, and may be observed swimming freely about in the cavity of the external gill. They are so different in form from their parent, and so singularly located, as readily to suggest the venial error of Rathké respecting their nature and relations. The hooked apex and the spines, with which the shell of the young *Anodon*, when first excluded, is armed, may serve to defend it against some small persecutor or other.

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* CCCXXX. p. 43. tab.

In the genus *Cyclas* Mr. Garner* has observed from ten to twenty of the young fry, situated in the internal branchiæ, where each has its special compartment: they are discharged one by one when they attain about the sixth of an inch in diameter. The oviducts in the *Cyclas* open over these internal branchiæ, and are only accessible to the water from behind, as are the external branchiæ of the *Unio*. The young *Cyclades* are sometimes found adhering by a byssus to different parts of the body of the parent. The young of the genus *Naias* have been observed to anchor themselves, after exclusion from the parent, by a byssus, which is usually wanting in the large and full-grown animals.

This temporary means of attachment must prevent many of the young and feeble bivalves from being carried away by the stream at a period when their shell has not attained sufficient hardness to protect them from the numerous predatory aquatic animals to whose attacks they would be exposed; and we may thus discern, in the deciduous byssus, an evidence of prospective design for the well-being of the weak and defenceless.

Prof. Edward Forbes, in an interesting paper published in the "Edinburgh New Philosophical Journal," has cited some facts of the periodical cessation of development of bivalves in certain shell-banks, and has alluded to the knowledge of such phenomena as being familiar to fishermen, who express it as being a "shifting" of shell-beds, which they erroneously attribute to the moving away and swimming off of a whole body of shell-fish, such as mussels and oysters. But even the Pectens, though much better endowed with locomotive power than the cemented oysters or byssus-bound mussels, have very little power of progressing to any distance when fully developed. With respect, however, to Prof. Forbes' opinion, that "the shifting or migration is accomplished by the young animals when in a larva state," this cannot be accepted as one of general application. The facts, at least, that have been ascertained in regard to the development of fresh-water bivalves are directly opposed to such migratory powers in the "larvæ;" for these are distinguished by organs of attachment which are peculiar to the immature state of the bivalve, and fetter them to their birthplace until, in the progress of growth, they attain freedom with maturity. I confess that I entertain great doubts whether the so-called "shifting" of shell-beds be the result of a migration *en masse* of the mussels or oysters, either in their larval or mature states; but deem it more probable that the disappearance of the bed of living individuals is due to their dying o through influences, which Prof. Forbes himself recognises and e plains, as unfitting the ground for further sustenance and increase the tribe; and that the appearance of a colony in another position due to the progressive increase from a few individuals, and not to t migration of the whole colony.

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* CCCXIV. p. 97.

So far as observations have been made on the development bivalves, although it is true that, as yet, they have been, wit few exceptions, limited to the fresh-water kinds, the young Lamell branch, however free the parent, is attached at the beginnin by a byssiform peduncle: it has no lamelliform gills, but respires b the vascular and ciliated surface of the mantle-lobes, and it has tw distinct hearts.

In all these characters we perceive the manifestation, though it b transitory, of some peculiarities of the Brachiopodous order; an hence we derive an additional argument for concluding that the Brachiopods are on a lower step of molluscous organisation than th Lamellibranchs: and this is congruous also with the earlier appearance and multiplication of the Brachiopods in the primeval seas this planet.

The contemplation of the phenomena of the development o *Anodon* also makes us comprehend better the cause of some of th peculiarities of the structure of the Lamellibranchiate mollusks There seems to be in that development a tendency, at the beginning, to form two individuals out of one germ-mass, — to develop two univalves in the place of one bivalve: and some of the difference of structure characteristic of different bivalves evidently relate t the arrest of development at given stages of the progressive confluenc by which the two primary individuals are ultimately fused into on Thus we may regard the two separate hearts of the Brachiopods a a retention of that distinctness or doubleness of the organ which i manifests at its first appearance in the embryo Lamellibranch, whe not only the auricles, but the ventricles, are on separate halves of th almost divided body. In *Arca*, the ventricles have approximate but not coalesced. In *Anodon* the two ventricles have coalesced but not the two auricles, which continue permanently separate, an impart the seemingly complex condition of the reptilian tripartit heart to this inferior form of mollusk. It has been long shown, however*, how the function of the two auricles of the bivalve being th same, that very doubleness or repetition of the part became a mark rather of inferiority, as compared with the more compact form of the single-auricled heart of the univalve mollusk; and we now see tha the circumstances under which the tripartite heart of the *Anodon* is developed, confirms that inference. In the Oyster the progress of union of the two individuals has proceeded to the confluence of both the two ventricles into one, and of the two auricles into one, and a bipartite heart is the result: unless, indeed, in this and in other inequivalves, one individual or moiety of the divided and embryonal mass be developed at the expense of the other, which may undergo partial absorption.

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* X. vol. ii. p. 33.

The ordinary course of confluence, by which, in the growth of the parenchyme from the line of union of the divided moieties of the embryo, the two intestines become one, commences, as regards the intestinal tube, from the anus; and, being followed or accompanied by the progressive co-approximation, co-adaptation, and ultimate confluence of the two ventricles, these, through the relative position of the rectum of each individual moiety, along the inner or mesial side of the originally distinct ventricles, come to be included between those co-adapting ventricles, and, ultimately, the single rectum becomes included by the single ventricle, each resulting from the fusion of a primitive pair; and hence we are able to comprehend the cause of that most singular anatomical fact which, hitherto, has been, without any intelligible explanation, a mere empirical one, viz., the passage of the rectum through the centre of the ventricle of the heart in most Lamellibranchs.

We may discern in that well-marked and peculiar feature of the Lamellibranchian development, viz., the almost complete fission of the embryonal mass, with the establishment, in *Anodon*, of digestive and circulating systems in each, an indication of the last remnant of the parthenogenetic force, which, in its complete manifestation, ceases with the Tunicata in the molluscous series. Nature, however, does nothing abruptly, and a transitional character to higher kinds of development of a single individual from a single ovum is indicated by this attempt, as it appears to be, to form two individuals out of one germ-mass. Their respective completion, however, as such, is checked; and development proceeds to form one (more complex) bivalve out of two (less complex) univalve individuals.

I may further remark, that the period and mode of the development of the two valves of the incipient bivalve are subversive of Oken's conjecture[*], that the operculum of the operculated univalve

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[*] Defining the univalve mollusks, Oken says, "Von den beiden Muschelschalen wird eine röhrenförmig, umschliesst das ganze Thier allein, und die andere bleibt als blosser Deckel übrig, der die Röhrenmundung schliesst."—*Lehrbuch der Philosophie*, Th. iii. p. 259. 8vo. 1811.

"Of the two mussel (*bivalve mollusks*) shells" (which he treats of in the preceding section), "one becomes excavated, tube-shaped, and alone incloses the is a stunted homologue of one of the valves of the bivalve, and esp cially of the smaller and flatter valve in the inequivalve bivalves.

Both valves are simultaneously and equally developed in the oyste as in the mussel, and form the peripheral layer of the germ-mas prior to the formation of any muscular organ : the recognisable basi of each valve is prior, indeed, to the fission of the germ-mass, whic is preliminary to the formation of the digestive and circulatin systems of the two primarily incomplete individuals. The oper culum, in the operculated univalves, is the subject of a much late growth ; it does not appear simultaneously with the proper univalv shell, nor is it ever equal to that shell in size or similar in shape Both the external temporary locomotive organs, I mean the vibratile cilia, and certain internal organs, are developed before there i a rudiment of the operculum in the univalve : even the permanen locomotive organ, the foot, is plainly established, before the operculum makes its appearance ; and when it does so, it is not as metamorphosis and coalescence of certain of the peripheral cells o the germ-yolk, but as a thickened epithelial layer upon the back par of the previously formed foot.

And whilst upon the subject of Oken's ideas of the homology o the operculum, we may as well test, by the light of molluscous embryology, some others which he has propounded relative to the natur of the bivalve shell.

"In the mussel," says Oken, "a structure originates for the firs time which can be compared with a thoracic cavity. What cover the branchiæ must stand in the signification of the thorax. Th pallium or mantle of the mussels is pleura. Their shells are branchia opercula (as in fishes). They are secretions from the mantle, an everywhere accompany the branchiæ. The hinge of the shell-valve corresponds to the rachis or spina dorsi. The shells of bivalv mollusks are a calcareo-thoracic box, open in front, inverted behind and moveable like ribs."*

Each valve in the Bivalve pre-exists, as we see, to any trace o gill : the first organs which it protects are the stomach, the liver and the whole length of the intestine ; it does not defend a thoraci or pectoral cavity, but an abdominal one. If the two valves ar comparable to opercula they are ventral, not thoracic or pectoral and the pallium, or layer of germ-mass lining the valves, in which

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whole body ; the other remains as the mere operculum, which shuts the opening of the tube." And in the edition of the same work, translated by the "Ray Society," Oken says, "With the one-sided evolution of the mantle, one shell als is only developed, while the other is stunted or placed under arrest. The snail's shell is one of the bivalve mollusk's shells, its operculum is the other. This last is stony, horny, and finally is entirely wanting."

* *Ib.* Th. iii. p. 254. 8vo. 1811.

the above-cited organs are formed, is peritoneum rather than pleura. The hinge of the valves is the unseparated, but modified, remnant of the germ-mass, which connects together the two individuals resulting from its incomplete fission: it is much more like the common pedicle or base of the compound Ascidian, than the "spina dorsi" of a vertebrate animal.

Thus we learn how valuable are the facts derived from the study of the progressive building up of the animal frame. In the case of the class which has this day occupied our attention, a knowledge of their development, partial and imperfect as it must be confessed to be, has nevertheless thrown new light on the peculiar organisation of the mature animal, has rectified misconception of the nature and homologues of their parts, and may have suggested truer theories of some of their more remarkable living habits.

Class LAMELLIBRANCHIATA.

Body with a dextro-sinistral bivalve shell, lined by a commonly more or less closed mantle. Oral tentacles four; branchiæ lamelliform, usually in two pairs.

A. MONOMYARIA. With one (the posterior) adductor.

Family *Ostreadæ.*

Lobes of the mantle widely separated; foot small, byssiferous, or absent. *Shell* inequivalve, slightly inequilateral; hinge usually edentulous.

Genera *Ostrea, Anomia, Placuna, Pecten, Lima, Spondylus, Pedum, Plicatula.*

B. DIMYARIA. With two adductors.

Family *Aviculidæ.*

Lobes of the mantle widely separated; foot small, byssiferous; anterior adductor very small, leaving its impression within the umbo.

Genera *Avicula, Meleagrina, Malleus, Vulsella, Gervillia, Perna, Crenatula, Inoceramus, Pinna.*

Family *Mytilidæ.*

Mantle-lobes united between the branchial and anal slits or orifices; foot cylindrical, byssiferous. *Shell* equivalve; hinge edentulous.

Genera *Mytilus, Myalina, Modiola, Lithodomus, Crenella, Dreissena.*

Family *Arcadæ.*

Mantle-lobes separated; foot large, bent, and deeply groove *Shell* equivalve; hinge long, with many denticles.

Genera *Arca, Cucullæa, Pectunculus, Limopsis, Nucula, Isoarca.*

Family *Solenellidæ.*

Mantle-lobes united behind, with a single siphonal orifice, or wit two short united siphons. *Shell* equivalve; hinge edentulous, or wit fine sharp teeth.

Genera *Solemya, Solenella, Yoldia, Leda.*

Family *Trigoniadæ.*

Mantle-lobes separated; foot long, pointed, sharply bent. *Shel* equivalve, trigonal; hinge-teeth few, diverging.

Genera *Trigonia, Myophoria, Axinus, Lyrodesma.*

Family *Unionidæ.*

Mantle-lobes united between the siphonal orifices and, rarely, i front of the branchial opening; foot very large, tongue-shaped, compressed, byssiferous in the fry. *Shell* usually equivalve; anterio hinge-teeth thick and striated, posterior laminar, sometimes wanting

Genera *Unio, Castalia, Anodon, Iridina, Ætheria, Mülleriæ.*

C. Dimyaria Siphonifera. With respiratory siphons.

a. Siphons short, pallial line simple.

Family *Chamidæ.*

Pedal and siphonal orifices small, subequal; foot very small. *Shel* inequivalve; hinge-teeth 2-1, or two in one valve, one in the other.

Genera *Chama, Monopleura, Diceras.*

Family *Hippuritidæ.* (*Rudistes,* Lam.; extinct.)

Shell inequivalve, unsymmetrical, thick, attached by the right umbo; umbones frequently camerated; hinge-teeth 1-2. Adductor impressions two, large; three of the left valve on prominences.

Genera *Hippurites, Radiolites, Caprinella, Caprotina.*

Family *Tridacnidæ.*

Pedal orifice large; siphonal orifices surrounded by a thickened pallial border, the anal one with a tubular valve; foot small, cylindrical, byssiferous. *Shell* equivalve, open; muscular impressions sub-central and blended.

Genera *Tridacna, Hippopus.*

Family *Cardiadæ.*

Pedal orifice large; siphons usually short; foot large, sickle-shaped. *Shell* equivalve, cordiform; cardinal teeth 2, lateral teeth 1, 1, in each valve.

Genera *Cardium, Hemicardium, Lithocardium, Serripes, Adacna, Conocardium.*

Family *Lucinidæ.*

Mantle usually widely open below, with one or two siphonal apertures; foot long, cylindrical, or ligulate, sometimes byssiferous. *Shell* orbicular, closed; hinge-teeth 1 or 2, lateral teeth 1-1, or obsolete.

Genera *Lucina, Cryptodon, Corbis, Ungulina, Kellia, Montacuta, Lepton, Galeomma.*

Family *Cycladidæ.*

Mantle open in front; siphons more or less united; foot large, tongue-shaped. *Shell* suborbicular, closed; hinge with cardinal and lateral teeth.

Genera *Cyclas, Cyrena, Pisidium.*

Family *Cyprinidæ.*

Mantle-lobes united behind by a curtain pierced with two siphonal orifices; foot thick or compressed, tongue-shaped. *Shell* equivalve, closed; cardinal teeth 1-3, and usually a lateral tooth in each valve.

Genera *Cyprina, Circe, Astarte, Crassatella, Isocardia, Cypricardia, Megalodon, Cardinia, Cardita.*

b. Siphons long; pallial line sinuated.

Family *Veneridæ.*

Mantle with a rather large anterior opening; siphons unequal, more or less united; foot tongue-shaped, compressed, sometimes grooved and byssiferous. *Shell* regular, closed; hinge with usually three diverging teeth in each valve.

Genera *Venus, Cytherea, Artemis, Lucinopsis, Venerupis, Petricola, Glaucomya.*

Family *Mactridæ.*

Mantle more or less open in front; siphons united with fringed orifices; foot compressed. *Shell* equivalve, trigonal; hinge with two diverging cardinal teeth, and usually with lateral teeth.

Genera *Mactra, Gnathodon, Lutraria, Anatinella.*

Family *Tellinidæ.*

Mantle widely open in front; foot tongue-shaped, compressed; siphons separate, long and slender. *Shell* usually equivalve and closed; cardinal teeth not exceeding two, laterals 1-1, someti wanting.

Genera *Tellina*, *Psammobia*, *Sanguinolaria*, *Syndosmya*, *Scr cularia*, *Mesodesma*, *Donax*.

c. Mantle sheath-shaped, closed, save at the pedal and siphonal apertures.

Family *Solenidæ*.

Siphons short and united (in the long-shelled genera), long partly separate (in the shorter and more compressed genera); g prolonged into the branchial siphon; foot large, subcylindrical. *S* gaping at both ends.

Genera *Solen*, *Cultellus*, *Machæra*, *Solecurtus*.

Family *Myacidæ*.

Siphons united; foot small. *Shell* gaping behind.

Genera *Mya*, *Corbula*, *Neæra*, *Thetis*, *Panopæa*, *Saxicava*, *G cimeris*.

Family *Anatinidæ*.

Siphons long, more or less united; foot very small. *Shell* of inequivalve.

Genera *Anatina*, *Thracia*, *Pholadomya*, *Lyonsia*, *Pandora*, *M chama*, *Chamostrea*.

Family *Gastrochænidæ*.

Siphons long, united to near the extremities; foot finger-shap sometimes grooved and byssiferous; mantle with a boring disc front. *Shell* regular, wedge-shaped, gaping in front, in some m or less cemented to a superadded calcareous tube.

Genera *Gastrochæna*, *Clavagella*, *Aspergillum*.

Family *Pholadidæ*.

Animal clavate or vermiform; siphons large, long, united nea to their ends; foot short and truncate. *Shell* gaping at both end hingeless, with sometimes accessory valves, or a supplementary tu and palettes.

Genera *Pholas*, *Xylophaga*, *Teredo*, *Teredina*.

LECTURE XXII.

PTEROPODA AND GASTROPODA.

ALTHOUGH the Acephalous Mollusca are for the most part deprived of the power of locomotion, or have it granted to them in a very low degree, yet some species of Lamellibranchs can swim, and the pectens, from their lively movements in the water, and the vigorous flappings of their brightly tinted valves, have obtained the name of sea-butterflies. Amongst the Mollusca provided with a distinct head locomotion is the rule. *Lithedaphus*, indeed, is fettered by its calcareous operculum to the rock on which it grows, and *Magilus* becomes immoveably sunk in its coral bed; but these are rare exceptions. Amongst the numerous free and locomotive Encephala, some creep, some climb, some swim; a few combine these different powers; whilst certain small species have no other mode of progression than by floating or swimming on the surface of the ocean. These are provided with two fin-like muscular expansions, attached to the sides of the neck, which, from their resemblance to wings, suggested to Cuvier* the name *Pteropoda* for this small but well marked group of Mollusks with heads.

Some Pteropods are provided with a light and delicate semitransparent shell. In the *Hyalæa*, it resembles a bivalve shell, of which the two valves had been cemented together at the hinge, leaving a narrow fissure in front and at the sides. In the *Cleodora*, the two plates of the shell are united together along the sides as well as at the base, leaving an opening only in front. The shell of the *Limacina* is a cone twisted spirally in one turn and a half. The shell of the *Cymbulia* is symmetrical, like a boat or slipper, but is cartilaginous. The *Clio* and *Pneumodermon* are naked, or without shells.

All the species of Pteropoda are of small size; they float in the open sea, often at great distances from any shore, and serve, with the Acalephæ, to people the remote tracts of the ocean. In the latitudes suitable to their well-being, the little Pteropoda swarm in incredible numbers, so as to discolour the surface of the sea for leagues; and the *Clio* and *Limacina* constitute, in the northern seas, the principal article of food of the great whales.

Those Pteropoda which have symmetrical shells composed of two plates have one applied to the dorsal, and the other to the ventral,

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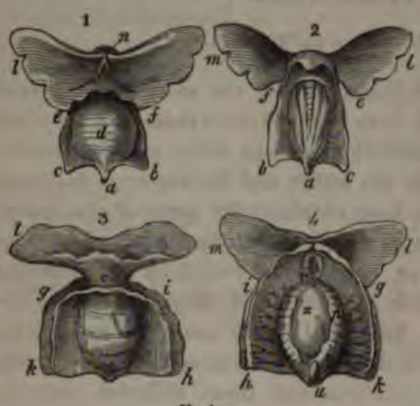
* CCCXXI.

surface of the body, as in the Brachiopods. The shell is bivalve
form, but the two valve-shaped plates are confluent at the pa
representing the hinge (*a*, *b*, *c*), and their free borders do not correspon

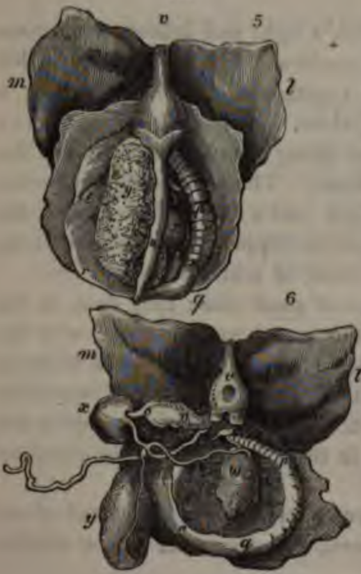
195



Hyalæa.

In *fig.* 195, No. 1 shows t
ventral surface of the *H*
alæa, with the head *n*, an
its wing-like muscular e
pansions *l*, *m*. The hind
or abdominal division of th
body is protected by th
shell, which terminates b
hind in three points,
b, *c*. The ventral plate
is the shortest and mos
convex: the dorsal plat
2, is nearly flat and oblong
The lateral borders of th
two plates, *c e*, *b f*, are sepa
rated by a long and narrow fissure, through which the extensile border
or appendages of the mantle can be protruded. The head and its fin
project from the wider anterior opening. The fins *l*, *m*, are supporte
on a short and thick neck o
pedicle (3, *c*): in the livin
animal they are of a bright yel
low colour with a deep viole
spot near their base, which, wit
their flapping movements, give
them a resemblance to the wing
of a butterfly. Between the fin
are two small labiate folds, in
cluding the mouth and the outle
of the penis.

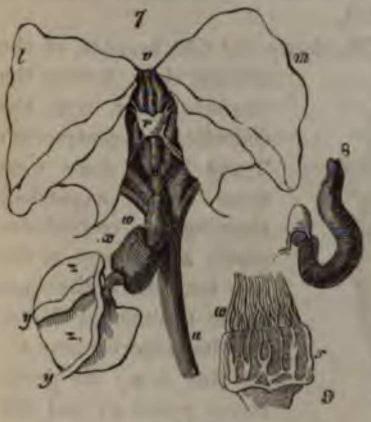
196



A cylindrical muscle (*fig.* 196
u) arises from the middle poin
(*a*) of the shell, and traverses th
visceral mass to be inserted int
the neck; it divides for tha
purpose into four short fasciculi
which diverge in the substanc
of the fins: other strata of mus
cular fibres decussate the pre
ceding obliquely in those loco
motive expansions. The nervou

system in this blind and non-tentaculate pteropod partakes of the simplicity of that in the bivalves; inasmuch as there is no ganglionic enlargement of the upper part of the œsophageal loop. The chief centre (*fig.* 197, *r*) consists of a large flat subquadrate subœsophageal mass, from the anterior angles of which proceed the chords encircling the gullet, and some nerves to the fins: the other nerves to the fins and those to the rest of the body are given off from the posterior angles of the great ganglion.* The acoustic vesicles are in contact with the fore part of this ganglion; they are large, and have otolites, kept in motion by the vibratile cilia of the inner surface of the vesicle. The lingual teeth are arranged in transverse rows of three in each; they are long and recurved. The œsophagus (*v*, *figs.* 196, 197) overlies the penis; it dilates into a kind of crop (*fig.* 197, *w*), which conducts to a cylindrical gizzard (*x*): both these have their inner surface produced into longitudinal folds (9), those of the crop (*w*) being more numerous than those of the gizzard (*x*). The intestine (*fig.* 197, *y*) is a narrow tube of uniform diameter, which describes two convolutions, bending towards the ventral surface, in the substance of the liver (*fig.* 196, 6, *x*, and 197, *z*, *z*). The anus is on the right side of the neck, beneath the right fin. In Sagitta the hepatic substance appears to be blended with the intestinal walls. In Pneumodermon the stomach is lined by a layer of small hepatic follicles. If the dissection of *Hyalæa* be made from the dorsal aspect, as in *fig.* 196, 6, the heart, which consists of an auricle and a ventricle, is seen on the left side upon the inner border of that end of the gill, *s*. This branchial organ is a long narrow body subdivided into small transverse ciliated lamellæ, and describing a curve which runs almost parallel with the border of the shell-cavity, *p*, *q*, *s*, *fig.* 196, 6, and *fig.* 195, 4. A contractile renal organ opens into the branchial cavity.

197



Hyalæa.

The male and female organs are combined in the same individual in all Pteropods. The ovario-testis (*fig.* 196, 6, *w*), presenting a structure like that in the snail (p. 561),* is a large oblong b placed in the middle of the visceral mass. A long and slender deferens, with which communicates a cæcal tube, communicates w the duct of a large albuminiparous gland or uterus (*fig.* 196, 5, occupying the left side of the abdomen: the common canal termina by an orifice anterior to the mouth. From this orifice the exciti organ (*fig.* 197, 8) can be protruded.

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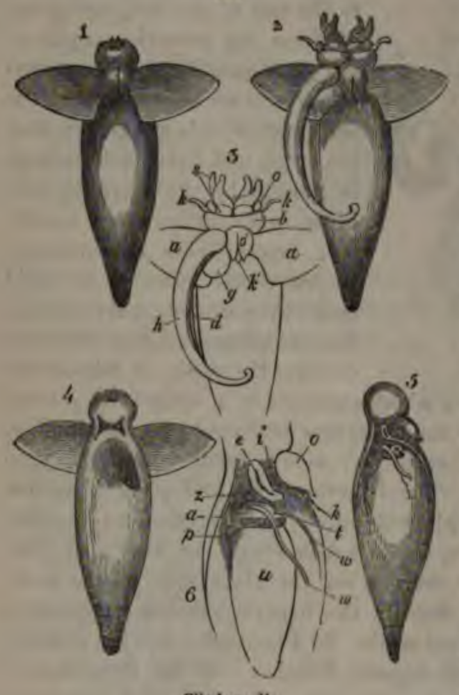
* Cuvier, owing to his opinion as to the dorsal and ventral aspects of the Hyalæa, describes this ganglion as the brain, CCCXXI.

Of the naked Pteropods, *fig.* 198, shows the *Clio borealis*, of t natural size: 1 from t ventral aspect, with t cephalic lobes contracte 2 and 3 the same, wi those lobes expande showing the conical c phalic appendages *s*, t two tentacles *k*, the ey *o*, the rudimental foot and its posterior lobe *k* the fins *a*, *a*; the gen rative pouch *g*; and t protruded intromitte organ *h*, along the co cave side of which ru the generative duct *d*. shows the animal fro the dorsal aspect, wi the cephalic lobes co tracted. 5 and 6 sho the animal, as seen fro the right side with t fins cut off, so as to e pose *e* the long orifice the accessory generati pouch; *i* the proper generative pore, and *t*, the anus: *p* is the "co strictor cervicis" muscle; *o* the rudimental foot. Each lateral lo of the head supports three of the retracted processes, which, whe fully expanded, form a radiated crown about the mouth. Each the six processes is perforated by numerous cavities, recognisable the naked eye as red points, but which consist each of a transpare sheath inclosing a central body composed of a stem terminated by tuft of about twenty microscopic pedunculated discs, the total numb of which in the head of the *Clio*, Eschricht, their discoverer

198



Clio borealis.

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* CCCXXX. † CCCXXIX.

estimates at 360,000! The head of the *Pneumodermon*, also a naked Pteropod, is provided with ocular tentacles; the mouth is covered by a large hood supporting two small simple tentacles, and two large processes beset with numerous pedicellate suckers. There is a small oval foot, with a pointed posterior lobe, beneath the neck, and a rudimental shell protecting the small branchial processes at the bottom of the visceral cavity.

The cervical aliform expansions of the *Clio* are muscular, like those of the *Hyalæa*, subserving locomotion, not respiration, as Cuvier believed. In swimming, the Clio flaps the ends of the wings in contact, first above, then below. The true branchial ciliated and vascular surface is developed in all Pteropods upon the inner surface of the mantle.

There are two slender and simple tentacula (*fig.* 198, 3, *k k*), which seem to exercise only the tactile faculty. Two superœsophageal ganglia are developed upon the upper part of the nervous collar which incloses the beginning of the alimentary canal; the two pedial and the two branchial ganglia are closely approximated and connected with the inferior and lateral parts of the nervous collar. From these centres the nerves are distributed to all the viscera and parts of the body. The acoustic vesicles receive their nerves from the subœsophageal ganglion, or the anterior pair, where the mass is subdivided, as in *Clio*. *Hyalæa* seems to be blind: most other Pteropods have eyes, and even the Sagitta has a pair of ocelli, forming two prominences on the top of the head, and resting directly on the ganglionic enlargement of the optic nerve.

The male and female sexual organs are combined in the same individual *Clio*: the duct of the voluminous ovario-testis communicates with a spherical albuminiparous sac, and is then continued to the base of the intromittent organ, which projects from an orifice on the right side of the head; it is almost as long as the body, and indicates that impregnation takes place by reciprocal coitus, as in many of the androgynous Gastropods. The sperm-reservoir is a pyriform vesicle with a short peduncle.

The development of the ova of the Pteropoda has not yet been observed; but the larvæ of some species have been detected; that of Pneumodermon has the end of the body encircled by two ciliated bands. Vogt affirms that two deciduous ciliated cephalic "vela" like those of the larvæ of most marine Gastropods precedes the development of the aliform fins.

Class GASTROPODA.

The transition from the *Pteropoda* to the present class appears
be made by the *Philliroë*, the *Glaucus*, the *Carinaria*, and the *Firo*
all floating pelagic genera remarkable for the delicacy of their tissu
and the rudimental character of their gastric foot. These aberra
Gastropods manifest the same affinity to the preceding group by t
presence, in some, of lateral, symmetrical, more or less aliform e
pansions, and, in others, of a shell characterised by its elegant sy
metry, lightness, and transparency; that of the *Carinaria* much r
sembles the shell of the *Cymbulia* in form, but is of a calcareo
texture.

The typical Gastropods, characterised by the greater developmen
especially the breadth of their ventral muscular locomotive disc, co
stitute a very extensive and widely distributed class of Mollusco
animals, many of which appear to have superseded the extinct i
habitants of the chambered shells in the organic economy of the e
isting shores. Most of the species are marine; many inhabit fre
waters; a few are terrestrial. They offer corresponding conditio
of the respiratory organs in relation to these media, with minor m
difications, of which systematic naturalists have availed themselv
in distributing the numerous and diversified members of the cla
into orders.

In certain small shell-less marine genera, *e. g. Rhodope, Tergip*
Eolidina, no distinct respiratory organs have been detected; the
form the order *Apneusta*.

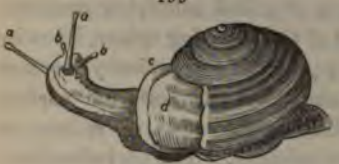
Where those organs are present they are, in the lower forms of t
class, exposed. The genera which support them on the back, or t
sides of the back, as the *Glaucus*, *Scyllæa*, *Tritonia*, form the ord
Nudibranchiata, in which all the species are without shells in t
mature state. Those genera which carry the gills at the lower part
the sides of the body, between the foot and mantle, as the *Phyllidi*
constitute the order *Inferobranchiata;* they are likewise naked wh
mature. The genera in which the gills have a similar position, b
extend around the body, as in *Patella* and *Chiton*, form the ord
Cyclobranchiata: they are defended by a conical shell composed
one or many pieces.

In the rest of the class the respiratory organs are concealed. Tho
genera, as the *Aplysia* and *Bulla*, which have the gills protected
a fold of the mantle containing a rudimental shell, or by a reflect
process of the foot, form the order *Tectibranchiata*. Those gener
as *Limax* or *Helix*, which have a vascular air-sac or lung, protect

by a rudimental, or fully developed shell, form the order ***Pulmonata.*** In all the foregoing orders of Gastropods the male and female organs of generation are associated in the same individual. In the remainder of the class the sexes are distinct. A small order of marine Gastropods, including the ***Fissurella*** and ***Haliotis,*** which have their pectinated branchiæ protected by a wide shield-shaped shell, is called *Scutibranchiata.* Another small group in which similar branchiæ are protected, with the entire body, by a tubular shell, is called ***Tubulibranchiata.*** In the last and highest organised order, called ***Pectinibranchiata,*** from the comb-shaped gills which have a special cavity at the fore part of the back, the males are provided with an intromittent organ.

The soft parts of the Gastropods are immediately invested by a soft inarticulated lubricous integument, forming, in most, a subcircular fold (*fig.* 199, *c*) about the neck, behind which it is dilated into a sac (ib. *d*) containing a portion of the viscera, which fold and sac are called the "mantle." In the skin may be recognised an epidermal, a pigmental, and a dermal layer, the latter being of a musculo-cellular structure and highly contractile. The epiderm is ciliated over nearly the whole body in the aquatic Gastropods, but only in certain spots in the terrestrial species. The white striæ at the sides of the neck and foot of ***Helix*** are composed of short, thickly-set, calcareous needles: the entire skin of ***Polycera*** and some other Nudibranchiates is studded with analogous ramified spiculæ.

199



Helix.

The shell results from the metamorphosis and calcification of cells deposited in layers beneath the epidermis, in the situation of the rete-mucosum in the human integument. In ***Limax*** and ***Clausilia*** the first trace of the rudimental shell is in the form of crystals of carbonate of lime in the substance of the mantle.* Its formation in the univalve Gastropods commences in the embryo, and the first-formed part is called the nucleus of the shell; the succeeding layers are not, however, formed around this, but are added to the inner surface of the circumference of the previously formed parts; and the proportions in which the new-formed layers extend beyond their predecessors determine the figure of the future shell. In some Gastropods, at certain seasons, the margin of the mantle, in which the shell-forming process is most active, extends outwards at an

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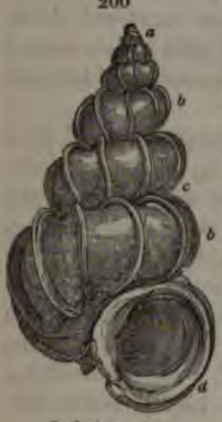
* CCCXLI. p. 372.

obtuse or right angle to the last-formed margin of the shell, and a
having formed a calcareous plate in this position, the mantle exte
in the ordinary direction, increasing the length of the shell, an
again similarly extended at a right angle with the last-formed pa
it is to this periodical growth of the mantle and plethoric condit
of the calcifying vessels that the ridges on the exterior of the sl
in the wentletrap (*Scalaria pretiosa*, *fig.* 200) are due. Should
margin of the mantle, instead of being u
formly extended, send outwards a number
detached tentaculiform calcifying process
these will form a row of spines correspondi
in length and thickness to the soft parts
which they are moulded; and, as the calcificati
of the processes proceeds, the spines, whi
were at first hollow, become solidified, a
finally soldered to the margin of the sh
This development of pallial calcifying process
or filaments, and of the resulting spines, likew
alternates with periods of the ordinary increa
of the shell; and thus its exterior surfa
may become bristled with rows of spines,
in the *Murex crassispina*. The periodical e
cretion of the excess of calcareous matter in t
blood is greatest in the carnivorous univalves.

200



Scalaria pretiosa.

The most simple form of univalve shell is the cone, which may
much depressed, as in the genus *Umbrella*, or extremely elevated a
contracted, as in *Dentalium*, or of more ordinary proportions, as
the Limpets (*Patella*). The apex of the cone is always oblique a
excentric; directed in the Limpets towards the head, but in oth
Gastropods towards the opposite extremity of the body. T
conical univalve shell is generally spirally convoluted. sometimes
the same plane, *e.g.* *Planorbis*, but more usually in an obliq
direction. The apex of the shell (*a*) is formed by the nucleus,
part developed in the egg: it is mammillated in *Fusus antiqu*
The spiral turns of the shell (*b b*) are called "whirls," the la
(*b*, *d*), being the "body-whirl."

As a general rule the spiral univalve, if viewed in the position
which its inhabitant would carry it if it were moving forwards fro
the observer, is twisted from the apex downwards from left to righ
the spire being directed obliquely towards the right; but in a fe
genera, *e.g.* *Clausilia*, *Physa*, the shell is twisted in the opposi
direction, when it is called "reverse" or "sinistral." Some individua
of *Bulinus*, *Partula*, and *Pupa*, and of a few marine species, as *Fus*

sinistrorsus, are sinistral. The part around which the spiral cone is wound is termed the "columella:" this is sometimes simple, sometimes grooved, sometimes plicated; in some shells it is solid, in some hollow; in the latter case its aperture is termed the "umbilicus" (*Solarium*).

The aperture which forms the base of the spiral univalve is bounded by an "outer lip" (*d*), and an "inner lip;" the latter offers a smooth convex surface, over which the foot of the Gastropod glides to reach the ground. In many univalves the aperture of the shell is entire; in others, the left side is formed only by the "body-whorl;" or the peristome (as the margin is called) may be broken by a notch, or perforated by one or more holes, or a portion of it be produced into a canal or siphon. These modifications are important on account of the constancy of their relation to certain conditions of the respiratory organs. Thus all the pectinibranchiate Gastropods, in which the water is conducted to the shell by a muscular tube or siphon, have the margin of the aperture of the shell either notched or produced into a canal. Sometimes there is a posterior channel which is anal in its function (*Strombidæ*): it is represented by a slit in *Scissurella*, a tube in *Typhis*, a perforation in *Fissurella*, and a series of holes in *Haliotis*.

The Gastropods which first appear in the palæozoic strata have entire mouths; the siphonated species are not found lower than the lias, and they go on increasing in numbers in and from the tertiary series to the actual sea shores.

In some of the Gastropods the shell consists of one piece, when it is termed an "inopercular univalve;" but the aperture of the shell is in the majority of the species closed by a plate, attached to the back of the foot, and called the "operculum" (*fig.* 208, *b*). This is sometimes calcareous, forming a second shelly plate; but it more frequently consists of albuminous membrane only, or is horny; thus presenting the condition which the shell itself manifests in certain genera, as *Limax* and *Aplysia*. Some opercula increase by the addition of matter to their entire circumference, and these are either concentric, as in *Paludina*, or excentric, as in *Ampullaria* and most of the Pectinibranchs. Other opercula grow by the addition of matter to part of their circumference, and these are either spiral or imbricated; in the latter the layers of growth succeed each other in a linear series. No operculum presents an annular form. Deshayes figures the operculum of *Solarium patulum* as composed of many distinct and spirally disposed lamellæ. Mr. E. Layard has discovered a similarly complex operculum in the *Cataulus Austenianus*, a little univalve of Ceylon. As the operculum sometimes varies in structure in the same genus, being horn in some species, and shelly in others of *Ampullaria* and *Natica*,—a it is present in some volutes, cones, mitres, and olives, and absent i other species of those genera,—and as some genera in a natura family, *e.g. Harpæ* and *Dolium* among the Buccinoids, are without a operculum, whilst the other genera of the same family possess tha appendage,—it obviously affords characters of secondary importanc in classification. In *Lithedaphus* (*Calyptræa*) *equestris* the whol base of the foot secretes a calcareous plate which is cemented to th rock, and the shell appears to consist of two valves. In the Chito the shell is divided into eight symmetrical pieces arranged like scale upon the back: the first of these is the smallest, the last the longes and most approaching the circular form.

In the interior of the shell the muscular impression is usuall crescentic, with the horns turned towards the head of the animal.

Most univalve shells are composed of three strata, which diffe in the arrangement of the calcareous particles: the innermost laye is nacreous in the fucivorous univales, *e. g. Patella, Haliotis,* an resembles enamel in the marine species. In *Cassis rufa* eac layer is composed of many laminæ, which are perpendicular to th plane of the main layer; and each lamina consists of a series o prismatic cells, adherent by their long sides: the laminæ of th outer and inner sides are parallel to the lines of growth, while thos of the middle layer are at right angles to them. In the Cowrie (*Cypræa*), there is an additional layer, which is nacreous, and forme by the over-lapping mantle-lobes when the animal has attained it full growth. Such shells are called "Cameo-shells," those ornament being formed by the removal of one layer, and the carving of th next. Hunter* discovered that the molluscous inhabitant of a shel had the power of absorbing part of its dwelling. This property which is now generally recognised, is well illustrated by the thinnin of the parietes of the internal whorls of the *Cones* and *Olives*, fron which two out of the three layers of which they were originall composed may be observed to have been removed. The absorptio of shell is also illustrated by the removal or smoothing down of th spines of the *Murices*, as the growing whorl expands and overlaps it predecessor; by the flattening of the inner lip of the mouth of th *Purpuræ;* by the widening of the fæcal aperture of the *Fissurellæ*, and it gives rise to various other modifications in the form an structure of shell in the progress of growth. Another change o form is due to the physical decomposition or destruction of a part o a shell during the lifetime of the inhabitant. This occurs to the apex of certain univalves after the shell has been evacuated by the original occupant in the widening and lengthening the shell to accommodate it to an increase of bulk: such shells are said to be "decollated," as, for example, the *Bulinus decollatus.*

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* Philos. Trans. 1785, p. 343.

The inhabitants of univalve shells dispose in different ways of that part of their calcareous abode which they evacuate in the progress of growth; in the decollated shells the vacated spire is portioned off, prior to its abrasion, by the formation of a thin nacreous plate. In the *Vermetus gigas* the vacated portions of the tube are retained, and successively portioned off, a series of concave plates or septa being thus developed. In the *Magilus antiquus* the posterior part of the shell, as the soft parts move forwards, is progressively filled up with a dense, solid, subtransparent, crystalline deposit of carbonate of lime.

Univalves which inhabit rocks upon which surf-waves are ever breaking, have stronger and denser shells than those that live in calmer seas, or in sandy and muddy bottoms. The shells of air-breathing mollusks exhibit analogous effects of external influences; those of the burrowing *Bulini*, e. g., are colourless and subtransparent; but the shell is vividly coloured in the species inhabiting plains with scanty vegetation and much exposed to solar light: the shells are largest and thickest in the arboreal *Bulini* of tropical forests, which live amongst an abundance of decaying vegetable matter.

The part of the mantle which invests the viscera in the conchiferous Gastropods is smooth, thin, and sub-transparent, resembling the sac of a hernia, which, with the viscera themselves, appears to have escaped from the common muscular integument of the body. This visceral mass, as it is termed, is lodged in the upper part of the cone of the shell, the spiral turns of which it follows. The head and foot of the animal can be protruded from the mouth of the shell, and be retracted within its last whorl, by the action of a muscle, which has its fixed point in the columella of the shell. This retractor, to which the operculum when present is attached, answers to the posterior retractor of the foot in bivalves. The form and size of the shell-aperture correspond with, and indicate the size of, the foot. In the pectinibranchiate Mollusks, which are the chief fabricators of the beautiful turbinated shells of the conchological cabinet, the foot is attached to the anterior part of the body by a narrow base; whence they have been termed by Lamarck *Trachelipods.*

The primitive muscular fibre is smooth in all Gastropods: the primitive fasciculi have often numerous nuclei scattered through them.

The cutaneous muscular layer consists of oblique, longitudinal and transverse fibres, intimately united with the corium. Upon th ventral surface it becomes very thick, and forms a long disc calle the "foot." The fibres of this part contract successively, so as t form wrinkles or transverse waves following each other from behin forwards; whereby the disc glides over solid bodies or the surface o water. The circular foot of the limpet is used as an adhesive sucker In some species it expands to a great breadth; in many it is ex tended lengthwise, and more or less cleft transversely; so that i some species three divisions may be indicated: the anterior of thes is distinct in *Natica;* the middle division forms the chief creepin disc; the posterior one supports the operculum, when this is deve loped. The posterior lobe of the foot in the inoperculate *Harpa* i said to separate spontaneously when the animal is irritated. In *Atalanta* it is compressed, but supports the operculum: it seem also to form the tail in the beautiful *Carinaria*, in which th middle part of the foot is reduced to a small suctorial disc, sup ported by a part the form of a fin.* This mollusk and its allies hence called *Heteropoda*, swim on their back with their locomotiv foot upwards. The tentacles, buccal mass, and penis, have thei special retractor muscles in most Gastropods.

In the living *Cypræa* and *Ovula* the mantle-lobes are observed t be in almost constant tremulous motion: but the most vigorou muscular efforts in Gastropods are those of the foot combined wit the retractor shell-muscle. The Strombs and Scorpion-shells thereb progress by successive jumps; the active Olives can turn over whe laid on their back, and bury themselves in the sand as the tid retires; the periwinkle advances alternately the sides of its longi tudinally indented foot; *Buccinum arcularia* defends itself by it dentated operculum.

At the grade of the Molluscous organisation which the Gastropod have reached, their capabilities and spheres of action become mor extended and diversified than in the Pteropods and Acephala; som are terrestrial, some arboreal, whilst the more numerous aquati species are endowed with power to attain, subdue, and devour organ ised matter, dead and living. The nervous system of the Gastropods is accordingly not only more complex and concentrated, no only subordinated to better developed masses in connection wit organs of special sense and exploration, but it offers greater variet in its general arrangement, and especially in the position of its gan glions, than in the Lamellibranchiate class, and with these modifications considerable differences in the outward configuration of th body are associated.

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* CCCVII. p. 198.

A few Gastropods, for example, are symmetrical, more or less flat, or depressed; others are compressed; the majority are contorted and lose their symmetrical form in an oblique twist: there are other diversities of organic structure which more immediately affect the condition of the nervous system, for some species possess both eyes and tentacles, whilst others are blind and akerous.

The nervous system has a distinct fibrous neurilemma, often charged with pigmental cells. The ganglion-cells are often pedunculated, and have usually a very large nucleus composed of obscure granules, in the midst of which are usually two to four transparent nuclei. The central part of the system surrounds the œsophagus, and consists of different parts, of which that which is above the tube, and which usually includes two contiguous ganglia, is called the brain.

In the limpet (*Patella*), and bubble-shell (*Bulla*), we find that the cerebral ganglions, as in the bivalves, are still distant from each other, and situated at the sides of the œsophagus, connected together by a nervous chord or commissure which arches over that tube: from these ganglions two filaments proceed backward on either side; the median and superior pair passes along the sides of the œsophagus, converges and meets below to form a pair of ganglions in close contact with one another which supply the foot and viscera: these are evidently homologous with the bilobed pedial ganglion of the *Mytilus*. The lateral and inferior filaments pass downwards to join two widely separated branchial ganglions, homologous with those situated on the posterior adductor in the *Mytilus*. We observe, however, a considerable difference in the relative positions of the pedial and branchial ganglions in the limpet; the latter have advanced into close contiguity with the pedial ganglions, and are connected with them by the same transverse chords, which in *Pecten* and *Mytilus* serve merely to bring the branchial ganglions themselves into mutual communication.

We thus observe in the lowest and least locomotive Gastropods a tendency in the nervous system to be aggregated at the fore-part of the body, the cerebral ganglions rising more to the upper surface of the now well-developed head, and the branchial and pedial ganglions beginning to concentrate themselves about the mouth. But this march of development does not prevent the homologies of the different ganglia from being satisfactorily traced. In the limpet there is a distinct head and mouth, with organs of special sense; and besides the large antennal and small ophthalmic branches given off from the cephalic ganglia, we find also superadded (infero-pharyngeal) ganglia, having evident relation to the muscular mouth and pharynx and to

the complex tongue, which are so many accessory parts appended
the simple opening of the gullet, with which the alimentary ca
commences in the bivalves. The additional ganglia in question
placed below the pharynx, and are brought into communication w
the sentient centres by a filament continued downwards and forwa
from each of these ganglia: they also inter-communicate by a l
which forms a third azygos rudimentary ganglion beneath
œsophagus completing an anterior ring corresponding to that wh
is formed by means of pedial ganglion posteriorly.

The ganglions corresponding to the pedial pair in the *Bullæa*
pear not to be joined together by a transverse band, but to be c
nected only with the branchial ganglion, and through them with
cerebral ones. The three are placed so close together, that Cuv
describes them as forming one mass. There are two pharyng
ganglia formed upon filaments descending from the cerebral ganglio
The labial ganglions, which are developed in addition to the ped
ganglions, originate from the latter in the *Bulla lignaria* and
connected, through them, with the cerebral ring.

In the *Haliotis*, the superior or œsophageal part of the œsophage
circle is still a simple commissural chord. The sides of the circle a
formed by a double chord, which unite below in a single branchi
pedial ganglion; from which the visceral, as well as the branchial an
muscular, nerves radiate. The cerebral ganglia are distinct an
connected by a commissure in *Janthina, Turbo, Lymneus,* an
Planorbis. The sub-œsophageal mass in the *Limnæus stagnalis*
of an orange-colour, and consists of seven ganglions united togeth
by a loose cellular tissue.

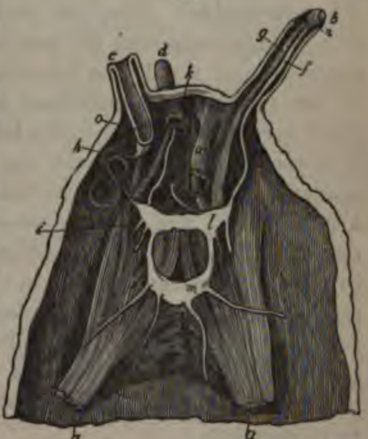
In the *Doris* and *Onchidium* the cerebral, pedial, and branchi
ganglions have coalesced into one annular mass, which, however,
chiefly super-œsophageal in its position, united below by a slend
chord passing across the under parts of the œsophagus. Two sma
nerves are given off, which descend and form two small pharynge
ganglia, which, according to Cuvier, are united together. In th
Doris Solea the quadripartite character of this large mass is howev
obvious. The olfactory ganglia are sessile in front of the cerebral
This is the general character of the nervous centres in other Nud
branchiate and Apneustal Gastropods. The optic ganglia are at th
back part of the cerebral, on which the acoustic capsules are sessil
The pharyngeal ganglia complete a small ring about the beginnin
of the œsophagus, and the pedial, or chief sub-œsophageal masse
with their intervening commissure, form the second and chief rin
The branchial ganglia are behind the cerebral; they supply th
skin of the back and the gills: beneath and sessile on their fro

border is the single visceral ganglion, from which proceed the nerves forming the plexuses about the viscera, which are in communication with the pharyngeal or anterior ganglia of this stomatogastric system of nerves.*

In the *Paludina vivipara* the super-œsophageal ganglions (*fig.* 204. *u*, *u*) are distinct, and connected together by a transverse commissural filament. The sub-œsophageal mass sends its principal branches to the foot; but one nerve comes off from the right side, crosses the œsophagus, and expands into a small ganglion *x*, which distributes its filaments to the retractor muscle that attaches the animal to its shell.

In the slug and snail (*fig.* 201.) the principal centres of the nervous system are a super-œsophageal (*l*) and a sub-œsophageal (*m*) mass; but the complex character of the latter and larger mass is indicated by the triple nervous chord, which completes on each side the collar round the alimentary tube. From the inferior mass the nerves radiate to the muscular foot, the soft and susceptible integument, and the circulating and respiratory organs. The upper ganglion receives the large nerves of the tentacles (*e f*) and ocelli (*n*); it also communicates on each side by two minute filaments, proceeding from its posterior and outer angles, with a small pair of stomatogastric ganglions situated on the side of the œsophagus.

201



Structure of the tentacles in the Garden-Snail (*Helix nemoralis*).

In the *Aplysia* the sub-œsophageal ganglionic mass is divided into two parts, which are joined together by a transverse chord, and brought into communication with the cerebral ganglions by ascending and converging chords. The cerebral ganglions are blended together above the œsophagus, and assume the position of a true brain. They supply nerves to the tentacles, and give off anteriorly two chords, which turn forwards to join below the mouth, where they form a second œsophageal collar upon which the pharyngeal ganglions are developed. The branchial ganglion is situated towards the posterior part of the body; the connecting chords of this ganglion join those of the pedial ganglia, but may be traced directly to t brain.

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* CCCXLVI.

The position of the cerebral ganglions varies according to t degree of extensibility of the mouth and œsophagus. Thus, in t *Helix*, they are placed above the mouth; in *Carocolla*, at the co mencement of the œsophagus; in the *Buccinum* or Whelk, near t end of the tube; in the *Purpura*, beyond the stomach.

As a general rule, we find that the superior ganglions give o tentacular, ocular, and oral nerves, whilst the inferior masses are t centres of the muscular, respiratory, and visceral internuntiate chord The latter have, in addition to the infero-pharyngeal centres, also posterior splanchnic ganglion, or pair of ganglions, from which plexus of nerves proceeds, in many Gastropods (*Carinaria*, *Doridium* *Pleurobranchus*). They are situated beneath the folds of the inte tine, communicate with the sub-œsophageal ring and the branchi ganglion, and supply the intestinal canal, liver, and genital gland In the spiral pectinibranchiate univalves, where the branchiæ an their nerves are twisted to the left side, it is the left branchia whic is atrophied, while the right one is of large size. The nerves ar similarly affected, the left one being filamentary; whilst the right i a large chord, and has the accessory branchial ganglion develope upon it. The principal œsophageal ganglionic circle is surround by a thick membrane, which, in the large Tritons, assumes almost cartilaginous hardness. A coloured pigment is not unfrequentl found occupying a position analogous to that of the arachnoid, be tween the dense outer membrane and the ganglions. In the *Limnæ* and in the *Planorbis* this pigment gives to the ganglions their orang or roseate hue.

Amongst all this diversity in the number, size, and position of th nervous masses, certain ganglia are obviously homologous with thos which have received determinate names in the lamellibranchiat Mollusks.* The branchial ganglions receive impressions from, an transmit them to, the gills: they communicate also with the brai and through that centre associate the gills with all other parts of th body. The pedial ganglion is more commonly divided than in th bivalves, and the two divisions are wider apart, in consequence o the great breadth of the foot. In those Gastropods which possess naked muscular mantle, we find a pallial ganglion associated with pedial one, as in the *Aplysia*. The cephalic ganglions assume th character of optic lobes concurrently with the constancy and bette development of the eyes; even when the organs of vision are mor than usually minute or wanting, these ganglions are always larger than in the Acephala, and more decidedly superior in position: they supply the acoustic vesicles in many Gastropods. When separate, they are united by a thicker communicating chord, and are larger in proportion to the nerves given off from them. With the cephalic ganglions, likewise, we find connected the labial and pharyngeal ganglions. The anterior of the aggregated ganglions, which form the sub-œsophageal mass in most Gastropods, are in immediate connection with the acoustic vesicles in *Pleurobranchæa* and *Paludina*, as in *Clio* and some other Pteropods. The functions of the other ganglions of the body seem to be limited to the automatic reception and reflection of stimuli.

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* CCCLVI. p. 488.

Soft, lubricated, and irritable as is the skin of the naked Mollusks, there are not wanting reasons for supposing it to be possessed of a very low degree of true sensibility. Baron Férussac, for example, states that he has seen the terrestrial Gastropods, or slugs, allow their skins to be eaten by others, and, in spite of large wounds thus produced, show no sign of pain.

The vascular inferior surface of the foot may, perhaps, take cognisance of the character of the surface over which it glides; but the special organs of the tactile sense are the tentacula or horns which project from the lateral and upper parts of the head. These are wanting in a few Gastropods, hence called *Akera:* they are sometimes two, and never exceed four, in number in the present class. In the snails and slugs they can be retracted by an act of inversion. The mechanism by which this is effected will be understood by referring to *fig.* 201., which exhibits the tentacles in different states of protrusion. Each tentacle (*b*, *c*, *d*,) is here seen to be a hollow tube, the walls of which are composed of circular bands of muscle, and capable of being inverted like the finger of a glove. From the common retractor muscles of the foot four long muscular slips are detached, one (*g*) for each horn; these run in company with the nerve (*f*) to each tentacle, passing within its tube, when protruded, quite to the extremity. The contraction of this muscle dragging the apex of the organ inwards, as seen at *c*, inverts it, whilst its protrusion is effected by the alternate contractions of the circular bands of muscle of which the walls of each tentacle are composed. There is, however, another peculiarity rendered necessary by this singular mechanism, by which the nerves supplying the sense of touch may be enabled to accommodate themselves to such sudden and extensive changes of position; for this purpose the nerves supplying these organs are of great length, reaching with facility to the end of the tubes when protruded, and in their retracted state the nerves are seen folded up within the body. In the figure, *a a* indicates the origins of the retractor muscles of the foot from the columella; *b*, the right superior tentacle fully protruded; *c*, the left superior tentacle partially retracted; *d*, the left inferior tentacle extended, and *o*, the right inferior tentacle fully retracted and concealed within the body; *f*, the nerve supplying the superior tentacle elongated by its extension; *g*, the retractor muscle of the same tentacle arising from the common retractor muscle of the foot, and inserted into the extremity of the tube; *h*, the nerve of the opposite side thrown into folds; *i*, the retractor muscle of the same tentacle contracted; *k*, the aperture through which the nerve and retractor muscle enter the tentacle *d*; *l*, the brain; *m*, the sub-œsophageal ganglion; *n*, the eye. In the *Cyclostomidæ* the tentacles are contractile, but not invertible.

The anterior is the normal or constant pair of tentacles; the posterior pair, which supports the eyes in the snail, is reduced to two short processes, which extend from behind the basis of the anterior tentacula in the *Turbo*, and which form slight projections from the outer side of the base of those tentacula themselves in the *Paludina* (*fig.* 204.), and in most Pectinibranchiata. In the Aplysia, however, which has four tentacula, the ocelli are sessile, and situated in advance of the bases of the posterior pair.

The eyes never exceed two in number in the Gastropods: they are always very small in comparison with the bulk of the body; they present their largest relative size in the Pectinibranchiata. In the preparation* from a large species of Murex, there may be readily discerned the sclerotic tunic with its anterior orifice, the expansion of the optic nerve posteriorly between the fibrous and the pigmental tunic, and the large spherical crystalline lens, covered anteriorly by the transparent corneal integument; between which and the lens there is a very small interspace for the aqueous humour and the pupillary circular opening left by the pigmental layer or choroid. M. Lespès has summed up the results of an extensive series of researches on the eyes of the Gastropods, by the following definitions of the leading types of their structure:—a lenticular crystalline lens; the vitreous humour fluid, non-adherent (*Helix*): a lenticular crystalline body; the vitreous humour thick and united to the lens: the crystalline lens thick and slightly convex; the vitreous humour viscous and slightly adhering thereto.

The existence of the sense of hearing in the Gastropods was inferred by Dr. Grant, long before the organ was detected: he justly concluded that the sounds emitted by the *Tritonia arborescens* under water, were doubtless intended to be heard by others of the same species. The very general existence of an acoustic apparatus under its most simple conditions, in the lower Mollusks, has been established by the discoveries of Siebold. It consists of two round vesicles, containing fluid and crystalline or elliptical calcareous particles, or otolites, remarkable for their oscillatory action in the living or recently killed animals. In the *Limnæus* (*fig.* 202.), the acoustic cells adhere to the posterior part of the anterior ganglions of the great sub-œsophageal mass (*a a*): *e* is the capsule; *f* the otolites. They held a similar position in the snail and slug, in which the number of otolites ranges from eighty to above a hundred. The acoustic sacs are easily recognised by submitting the head of the smaller species of Gastropod, or of the young of the larger species, to a gentle compression under the microscope. The movements of the otolites, due to the action of vibratile cilia, is truly, as Siebold remarks, "a wonderful spectacle."

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* No. 1628.

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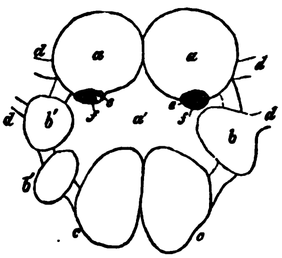

Limnæus stagnalis.

From the analogy of the soft mucous skin of the Gastropods to the pituitary membrane of the nose, Cuvier was led to conjecture that it might be the seat of the sense of smell; but the analogy seems to be too vague to render so general a diffusion of the nerves of a special sense very probable. That the sense is possessed by these Mollusca, is determined by the evidence which snails afford of scenting their food: the structure which best suggests the olfactory function is that which the two conical tentacles present in *Doris*, *Tritonia*, and *Scyllæa*. The confluent tentacles forming the cephalic lobe in the *Bullidæ* may have the same function.* It is remarkable that the laminated dorsal tentacles of the Nudibranchs, which seem never to be used as organs of touch, are supplied with nerves from the fore part of the super-œsophageal ganglions.

The tongue is, in almost all the Gastropods, a mechanical organ for the attrition of the food: its complex horny unciuated armature seems to unfit it for the delicate office of appreciating the sapid qualities of nutritive substances; but some sense of taste may be exercised by the soft membranes of the pharynx.

The Gastropods are organised to subsist on a great variety of food: they select both animal and vegetable matter in both their living and decomposing states. The damage which the common slug and snail do, by devouring the produce of the garden, is too w known: the whelk preys upon its congeners, nor do their stro shells defend them from its attacks.

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* CCCXLIX. p. 189.

The mouth is always anterior, and is bounded by fleshy contracti lips. These are developed, in *Haliotis*, into a pair of labial processe it is likewise generally armed with horny plates, trenchant or spin disposed either as jaws, or covering the tongue. The upper lip the snail is armed with a crescentic dentated horny jaw, which opposed by the bifid soft lip below. In the Tritonia, a curv trenchant horny plate works vertically upon another of similar for and with these, as with a pair of curved scissors, this mollusco animal crops the tough sea-weed which constitutes its food. Certai fresh-water Gastropods, as *Limnæus* and *Planorbis*, combine tw lateral horny jaws with a superior dentated labial plate. The Limp rasps marine plants with a narrow horny plate or ribband beset wit numerous (160) rows of minute recurved hooks (supported by th tongue, *fig.* 203. A)*, which armature extends beyond the mouth, an is longer than the entire body. The apparatus is supported by two firm parts (*b*, *b*), from which arise the muscles (*a*, *a*) that work the rasp. A magnified view of the arrangement of the lingual teeth is given at B. These teeth are amber-coloured, transparent, insoluble in acid: plainly silicious in the limpet and most other Gastropods. It is only the fore part of the tongue (*d*) that these teeth have the requisit hardness: when worn down the part supporting them goes, and th waste is supplied by the progressive growth, with concomitan hardening, of the lingual plate (*c*) behind. The soft reserve portio of the spiny tongue is found folded sub-spirally beneath the viscer of the Limpet.

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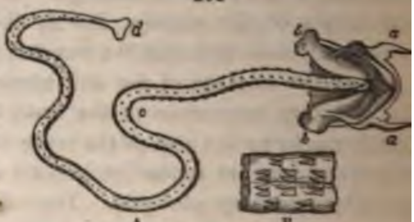

Tongue of *Patella*.

The whelk is provided with a more complicated instrument in th shape of a proboscis, susceptible of considerable elongation, or being entirely concealed within the interior of the body. Its extremity is vertically cleft, the divisions or lips having their inne surface beset with recurved spines. In the interior of the muscula cylinder, there is a tongue armed by an uncinated ribband, as in th Limpets, but of much less length: it is stretched upon two elongate cartilages, which can recede from or approximate each other, or be moved together to and fro, by special muscles: by these movements the spines can be made to scrape with force, the action being like that of a convex saw against any opposed surface; and it is by the repetition of such movements, aided, perhaps, as Cuvier conjectures, by a solvent property of the saliva, that the whelk effects the perforations in the hard shells of other mollusca, upon the soft parts of which it preys. In many other Pectinibranchs the mouth has the form of a retractile proboscis (*Cypræa*, *Murex*, *Voluta*, *Paludina*, *fig.* 204. *p*). In *Doris*, and most other Nudibranchs, the tongue is beset with the siliceous spines. Excellent descriptions and figures of the lingual dentition in the present class will be found in CCCLVIII. and CCCLIX.

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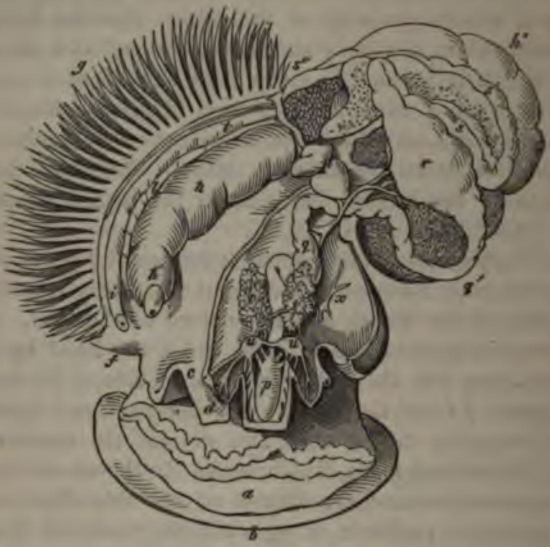
* CCCXXXVIII.

The salivary glands present different forms and degrees of development in different Gastropods, bearing the ordinary relations to the construction of the mouth and the nature of the food. They are usually two in number: their ducts, which are lined by a ciliated epithelium, open into the oral cavity on each side of the tongue. In the *Calyptræa* I found the salivary glands represented by two simple elongated secreting tubes: they also present the tubular form in *Aplysia*, *Thetys*, and many Nudibranchs. In the whelk they present a conglomerate structure, are situated on each side of the œsophagus, at the base of the proboscis, along which they transmit their slender ducts to terminate on each side the anterior spines of the tongue. In the *Paludina vivipara* (*fig.* 204.) the salivary glands are shown at *v*: their structure consists of ramose cæca. In the vegetable-feeding slugs and snails, the salivary glands are largely developed (*fig.* 207 *a.*): they expand upon the sides of the stomach, partially blend with each other and encompass that cavity, sending their long ducts, *a*, forwards to the mouth, and are readily distinguishable by their whitish colour. In many proboscidian pectinibranchs the salivary glands are placed in the abdomen, and have long and tortuous ducts, adapted to follow the movements of the dentated proboscis, near the anterior end of which they terminate. In a few Gastropods, e. g., *Janthina*, *Actæon*, *Atalanta*, there are two pairs of salivary glands.

A common type of the divisions and disposition of the digestive canal in the Gastropods is exhibited in the common river-snail (*Paludina vivipara*, *fig.* 204.) The œsophagus *q* is long and slightly convoluted; *q′* is the last bend which the tube makes before expanding into the stomach, *r*: *s*, *s′* show the folds of the intestine in the substance of the liver and ovary; it penetrates the branchial chamber at *s″*, in which the rectum, *t*, is seen passing along the base of the pectinated gills, *g*, to terminate at *i*, close to the margin of the mantle *f*, which forms the branchial aperture. The letter *a* indicates the foot in its state of contraction, when its inferior or ambulatory surface is bent transversely upon itself: *b* shows the operculum attached to the posterior part of the foot: *c* are the tentacula with the attached ocelli: *d* is the small siphon which projects below the right tentacle: *n* is the heart, which consists, as in almost all Gastropods, of a single auricle and ventricle: *h* is the long and wide oviduct, which performs the office of the uterus in this ovoviviparous species: *l* is the duct of a mucous or renal organ attached to the walls of the branchial cavity.*

204



Paludina vivipara.

The disposition of the viscera of other Gastropods offers few important deviations from that in the *Paludina vivipara;* but some of the peculiarities in the structure of certain organs deserve special mention.

The œsophagus is comparatively short in *Helix* (*fig.* 207. *c.*), and shorter in *Thetis* and *Haliotis.*

In a few Gastropods, the pond-snails (*Lymnæa, Planorbis*), for example, the œsophagus presents a small ingluvial dilatation: in the whelk (*Buccinum*) a crop-like cæcum is developed from the cardiac end of the stomach. The gastric crop is wider in *Aplysia,* in which the coats of the second stomach, or gizzard (*fig.* 205.), are thickened, and the interior callous lining is beset with firm horny processes, some in the form of hooks or canine teeth, others in that of rhomboidal plates or molar teeth. These complexities relate to the low organised character of the food of the *Aplysiæ:* the sea-weed on which these Mollusks subsist, after coarse mastication and commixture with the salivary secretions, is macerated in the crop, conveyed to the stomach, there pierced by the gastric spines, percolated by the solvent juices, and pounded by the horny plates. The chyme is then mixed in the duodenum (*a*) with the hepatic secretion, and with the fluid, probably analogous to pancreatic juice, which is secreted by a single long blind glandular sac (*b*), communicating with the beginning of the intestine. A similar simple form of pancreas is present in some species of *Doris*, and other fucivorous genera of Gastropods, as *Tritonia* and *Scyllæa*, which likewise have horny gastric teeth. In the *Bullæa aperta**, in which the tongue is not armed with teeth, the stomach is surrounded with three large horny plates, concave externally and convex towards the cavity. In the *Bulla lignaria*† the gastric triturating plates are calcareous: two of these plates present an irregular triangular form, with the angles rounded off, slightly concave externally, and convex towards the gastric cavity: they are united together by strong transverse muscular fibres attached to their circumference, except at the upper part of the gizzard, where a third valve of an oblong form is interposed between the two lateral ones. The imposition of the name *Gioenia* upon the large gastric plates of the *Bulla*, as the valves of a new bivalve shell, which was sold, whilst the deception lasted, at fabulous prices, will not soon be forgotten by conchologists.

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* CCCXXI.

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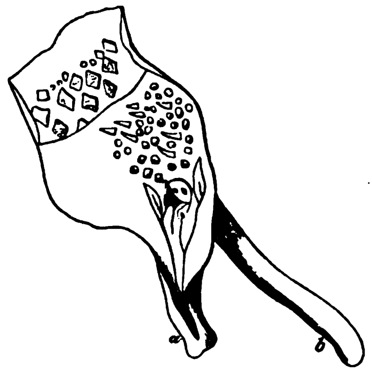

Stomach of Aplysia.

In regard to the number of cavities, the most complex stomachs in the *Gastropoda* are those of *Onchidium*, which has three longitudinally plicated gastric compartments, and of *Pleurobranchus*, in which they resemble those in the Ruminants. The first stomach (*fig.* 206.*a*), which is membranous, receives the bile by a large orifice (*b*) placed near its communication with the second digestive cavity

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* Preps. Nos. 493. 494.

† Prep. No. 492.

(*c*), which is smaller and more muscular; to this succeeds a third (*d*), the sides of which are gathered into broad longitudinal lamellæ, precisely similar to those of a ruminant; and to render the analogy still more perfect, a groove is found running along the walls of the second cavity from one orifice to the other, apparently subservient to rumination. The fourth stomach (*e*) is thin, and its walls smooth. This animal feeds on Alcyonia and small Zoophytes.*

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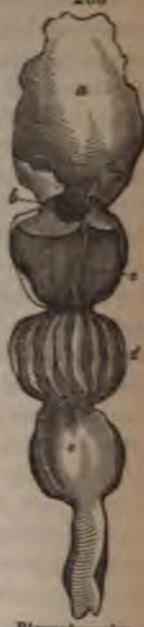

Pleurobranchus.

The intestine, after performing a few convolutions in the substance of the liver and generative gland, always more numerous, and of greater width in the herbivorous than in the carnivorous Gastropods, terminates, with a few exceptions, at or near the entry of the respiratory cavity on the right side of the body. The anus has a median position in the *Doris* and *Testacella*, and terminates on the left side of the body in the Planorbis.

In the *Apneusta* the alimentary canal departs so widely from the ordinary gastropodous type, as to have led some anatomists to regard it as a ground for their separation from the class.† Cæcal appendages extend from the stomach, which, in most, are ramified, and in some (*Eolis*, *Tergipes*, *Zephyrina*) are continued into the dorsal appendages.‡ But in all there is a rectum, terminating by a vent, which usually opens on the right side of the fore part of the body. The biliary secreting cells, in these little Gastropods, are developed in the walls of the gastric cæca, most abundantly at their blind ends.§

In the other orders of Gastropods the liver is a distinct and usually bulky gland, subdivided into numerous lobules of a yellowish-brown or brownish-green colour; so disposed as more or less to envelope the intestinal convolutions (*figs.* 204. 207. *h*, *h*). Its secretion is derived from arterial blood, and is usually poured by one or two ducts into the commencement of the intestine. It is carried, however, into the stomach, near the pyloric orifice in *Limax*, *Helix*, *Testacella*, *Doridium*; and even into the œsophagus, in *Onchidium*, by two of its ducts, the third opening into the first stomach. The *Haliotis* not only resembles the Palliobranchiata in the perforation of the stomach by the bile-ducts, but likewise in the perforation of the ventricle of the heart by the rectum, and in the division of the auricle into two cavities.

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* CCCXXI.

† Under the term *Phlebentères*, *e. g.* by Quatrefages, CCCLXII.

‡ CCCXLIII.

§ CCCLVI.

The blood of the Gastropods is often opalescent, with a few colourless corpuscles or cells, having an indistinct granular nucleus.

The auricle is divided in *Fissurella* and *Chiton* as in *Haliotis*. Both auricles, however, equally receive the oxygenated blood from the respiratory organ, as does the single auricle (*fig.* 207., *o*) in all the other Gastropods. The ventricle (ib. *p*) propels the blood to the viscera and muscular system of the body, and the heart is thus systemic, co-ordinately with the condition of the muscular system and the general endowments of the animal.* The heart is situated on the right side of the back in the *Pulmonata*, most *Tectibranchiata*, and the dextral *Pectinibranchiata:* it is on the opposite side in *Ancylus*, *Haliotis*, and the sinistral Gastropods: it is to the left of the dorsal median line in *Carinaria*; and near the hinder end of the body in *Firola* and *Atlanta*. The heart has a distinct pericardium in all Gastropods save the *Apneusta*, where it is not clearly defined. The aorta, continued from the apex of the ventricle, divides into two principal branches in most of the Gastropods. The auriculo-ventricular aperture is usually defended by two semilunar folds. The aorta, at its commencement, is frequently strengthened and enlarged by a muscular layer, similar to the *bulbus arteriosus* in fishes, and which, in the Aplysia, is continued beyond the origins of the primary branches of the aorta. The ramifications of the aorta, as in Crustaceans and Insects, are sooner or later lost in veins which expand to form sinuses, occupying the lacunæ of the viscera and other organs of the body.† The anterior aorta terminates, *e. g.*, in *Patella*, *Triton*, *Haliotis*, in a large lacunar sinus containing the brain, the salivary glands, the œsophagus and retracted tongue. The resumption of the normal vascular character by the venous system is more or less sudden: and is best exemplified near the respiratory organ upon which such venous trunk ramifies, like an artery, without any interposed branchial or pulmonic heart. The large venæ cavæ of the Aplysia, *e. g.*, are perforated by minute apertures, communicating with the great sinus that lines the cavity of the abdomen; and the exterior of those veins is provided with decussating muscular fibres, which probably regulate the diameter of such communications. The diffused condition of the vascular system most prevails in those Gastropods in which the respiratory organs are least developed, *e. g.*, the Apneusta. In the rest of the class the general modifications of the respiratory organs are indicated by the characters of the orders already defined. In the terrestrial Gastropods the breathing organ has the form of the simple undivided vascular sac (*fig.* 207. *m n*) like the lung in the lowest air-breathing Vertebrate animals: its orifice *m*, is on the right side near the head. The forms of the aquatic breathing organ are as various as is its position.

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* LXXXIV., p. 7.

† CCCXLI., CCCXLVII.

In most of the Nudibranchiate species the gills are tufted and ramified, as in the higher Anellides; they are penniform in the Haliotis, and pectinated in all the diœcious Gastropods (*fig.* 204. *g*), as the name of their order indicates: in these they never exceed two in number, which are of unequal size, and the branchial chamber is usually prolonged into a siphon. In a few genera of amphibious Gastropods a pulmonary sac is combined with branchial organs. The branchial surface is ciliated in all the Gastropods, as is also the exterior surface of the body in the small fresh-water species.

As a compensation for the absence of gills, some *Apneusta* (*Actaeon*, e. g.), have an aquiferous system, consisting of a reservoir, filled with water, behind the heart, from which branched canals pass off in all directions, one of which, according to Vogt, opens on the right side behind the vent. Conspicuous aquiferous pores are situated at the centre of the foot, in *Cypræa*, *Conus*, and *Ancillaria*, and at its margin in *Haliotis*, *Doris*, and *Aplysia*. Della Chiaje * has described a similar system in many of the higher organised Gastropods.

Besides the large and well developed hepatic and 'salivary' glands which are associated with the alimentary canal, we have seen that certain fucivorous Gastropods present the simplest rudimental condition of the pancreas. The situation of the follicular urinary gland and of its excretory duct has already been pointed out in the *Paludina vivipara:* in some species the duct dilates to form a small receptacle.† A group of follicular glands, sometimes imbedded in a distinct glandular sac, is present in many species for the elimination of some peculiar and characteristic colour; the yellow liquid of the *Bullæ*, and the famous purple secretion of the *Purpura*, are products of saccular modifications of this follicular gland, which is situated between the heart and liver. Numerous simple and scattered follicular glands lubricate the mantle with its characteristic mucus in all the Gastropods. In several terrestrial species, the median line of the foot is occupied by a straight canal, lined with ciliated epithelium, which ends in a large orifice beneath the mouth. On each side of this canal are rows of follicles which secret a granular mucus.‡ A follicle excreting a similar mucus opens on the extremity of each dorsal or lateral lobe in the *Apneusta* with those appendages. Some peculiar scent-follicles must exist in the garlick snail (*Helix alliaria*). A species of slug, called *phosphorax*, is slightly luminous.

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* CCCLXXIII. † CCCLX, p. 13. and CCCLXI. ‡ XXIV. p. 343.

Gastropods have the power of repairing injuries and of reproducing lost parts to a considerable extent. New tentacula soon grow to replace those which may have been amputated. When they support eyes, as in the snail, the organs of vision are also reproduced: the mouth, with the horny jaw, has grown again in this Gastropod; and when the snail has been decapitated, but with the œsophageal ganglions left behind, the head has been restored.

The general conditions of the sexual system have been already briefly defined. The complexity and bulk of the combined organs in the common slug and snail are truly extraordinary. The essential organs, testis and ovarium, are associated together in the form of a small, compact gland (*fig.* 207, *q*)*, composed of many parallel cæca, imbedded in the substance of the liver, and occupying, in the snail, the apex of the shell. Each cæcum consists of an external layer, producing ova, and an internal sac, folded in the first, producing semen.† The walls of these invaginated sacs are usually in contact, but become separated at the points, where the ova push the ovarian sac outwards, and the sperm-cells the testicular one inwards. The common ducts from these series of combined sacs are also invaginated, the oviduct being external, the sperm-duct internal, and usually undulated. The testicular cæca and sperm-duct are lined with ciliated epithelium: this is not present in the ovarian sacs.

Both invaginated tubes (*r*) enter the albuminiparous sac (*s*), and separate where they quit that part: there is a dilatation or sperm-reservoir, where the sperm-duct quits the base of the albuminiparous sac, and this latter may be regarded as a more special dilatation of the oviduct, with follicular walls. The sperm-duct, enlarged and with more glandular walls (*t*), now proceeds with many short folds parallel with the uterus to the base of the penis. This is a long and slender organ (*v*), usually retracted and concealed within the visceral cavity, but, like the finger of a glove, capable of being everted and protruded externally. The so-called "uterus" (*u*) is a long canal, with transversely plicated glandular walls, terminated by a vagina opening into the common genital vestibule, the external orifice of which is near the mouth of the respiratory sac, on the right side of the head. With the vagina there communicates the duct (*z'*) of a small pyriform vesicle (*z*), which is a sperm-reservoir, for the fecundating element of another individual received in coitu. A small cæcum is developed

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* CCCXIII. p. 370.

† CCCLXIV. p. 378.

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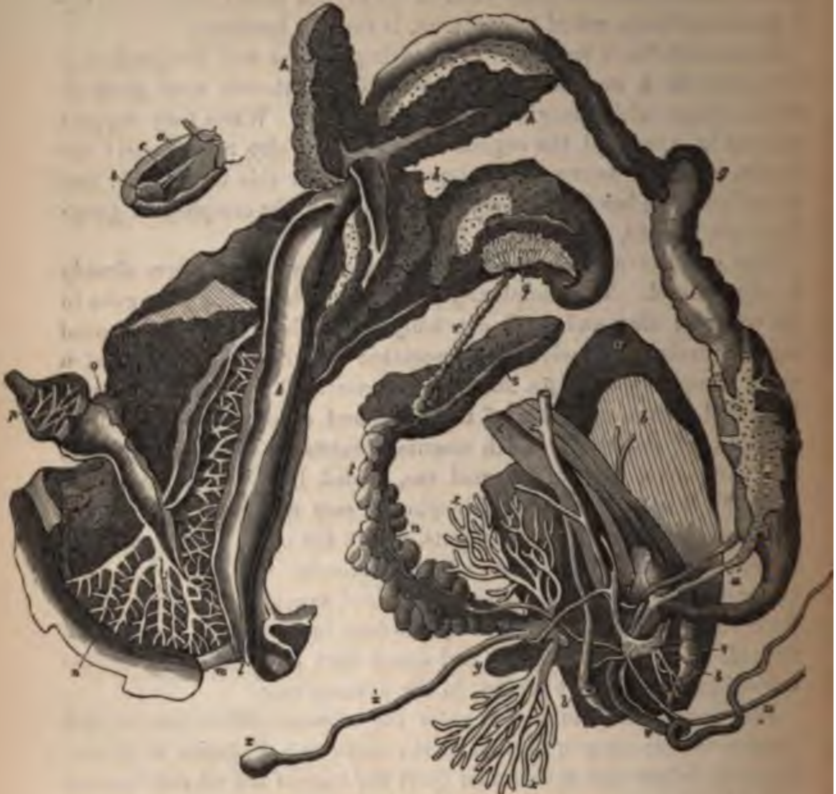

Helix pomatia, dissected.

from the duct in *Helix pomatia*, and a very long one in *Helix arbustorum:* the duct is short and simple in the slug (*Limax*). The genital vestibule receives the terminal outlets of two groups of branched cæca (*x*, *x*), or "multifid vesicles," the function of which is unknown. But the complexity of the generative apparatus does not end here: the snail is provided with a pyriform muscular sac (*y*), the aperture of which terminates close to the generative outlet. The expanded base or head of a slender conical calcareous style or dart (*b*, in the detached figure) is attached to the fundus of the sac (*a*); its sharp apex (*c*) extends close to the orifice, and by the contraction of the sac it can be protruded outwards. With it the snails pierce each other's skin, and the function of this curious organ would seem to be to cause a preliminary excitement to the reciprocal union of the two androgynous individuals.

The modifications of the parts of the complex combined organs of the androgynous Gastropods are manifold. In regard to their ultimate terminations or outlets, a common genital orifice is found in *Doris*, *Tritonia*, *Thetis*, *Bulimus*, *Clausilia*, and *Limax*, as in the above described *Helix*. In *Planorbis* and *Physa* the male and female orifices are situated side by side; the male in front, on the left side of the neck, behind the tentacle. In *Bulla*, *Bullæa*, and *Aplysia*, the male orifice is under the right tentacle, the female one much further back. In *Doridium* the male orifice is beneath the left tentacle; the female one on the same side, but near the opposite end of the body. In *Onchidium* the female orifice is situated close to the anus at the posterior end of the body; the male orifice is beneath the right tentacle. In all cases where the male and female organs are separate, a furrow may be traced from one to the other: the penis, when everted, projects from the male orifice.

The diœcious Gastropods form two sections, in one of which the copulatory organs are wanting, in the other highly developed. The non-copulants include the *Cyclobranchiata* and *Scutibranchiata*; the other section comprises the operculated *Pulmonata*, the *Heteropoda*, and the *Pectinibranchiata*. In these the intromittent organ is usually of extraordinary length: it is grooved in most, perforated in a few; capable of retraction in the *Paludina*, but doubled back upon the outside of the mantle when drawn into the shell by the *Buccinum* and *Strombus*. In the *Carinaria* it is bifid.

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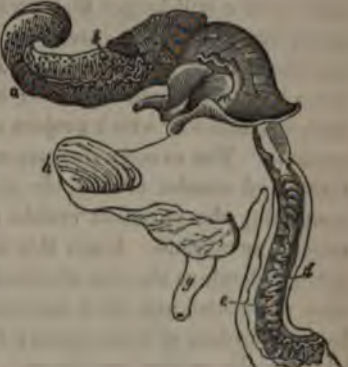

Male organs of Buccinum.

The internal organs of the male whelk, represented in the annexed figure, consist simply of a testis and sperm-duct. The testis (*a*) is of considerable size, sharing with the liver the smaller convolutions of the shell; from this arises the vas deferens, which forms by its convolutions a kind of epididymis (*b*), and then increasing in diameter enters the root of the penis, through which it passes by a tortuous course (*d*) to the tubercle at the extremity of this organ, where it opens externally. The penis is composed of strong transverse fasciculi of muscle, with lacunar sinuses, which together cause the erection of this organ: the muscles will at the same time lengthen it, and straighten the zig-zag turns into which the vas deferens is thrown in its usual relaxed state.

In the female the position of the testicle is occupied by the ovary, while the vas deferens is represented by a thick and glandular oviduct. There is no rudiment of exciting organ (clitoris): the generative aperture is situated a little within the edge of the branchial cavity, and is a simple hole leading to the oviduct.*

In *Murex* the penis is proportionally smaller; and, instead of a complete vas deferens, penetrating to its extremity, there is merely a groove along its surface, along which the semen flows. In *Voluta* the exterior groove only runs to the base of the penis, and in *Strombus* the male organ is a mere tubercle.

In the *Pulmonalia operculata* the organs of both sexes are in every respect similar to those of the Pectinibranchiate order. In *Paludina* (*Helix vivipara*, Lin.) the penis is closely united to the right tentacle, and, like it, is retractile. The ovarium, in the female, is shown in *fig.* 204. by its lighter colour, combined with the liver and intestine, with which it is lodged within the upper whirls of the shell. The oviduct (*h*) is susceptible of considerable dilatation at the breeding season, the young being developed therein: it terminates just within the branchial chamber.

In the male Limpet the testis is situated beneath the liver; its duct passes forwards and terminates near the vent on the right side. The ovarium and oviduct have the same disposition in the female. The *Haliotis* differs merely in having the genital orifice on the left side. The spermatozoa in these non-copulant Gastropods have a long body with a still longer filamentary tail: in *Paludina* the body has a spiral form, as is the case, likewise, with the shorter body of the spermatozoa of the *Helix* and *Limax*. In the sperm of *Paludina* there have also been observed long cylindrical bodies, from one of the extremities of which project many delicate filaments having lively motions. The ovarian ova present a round and sometimes elliptical form, and consist of a finely granular and variously coloured yolk, containing the germinal vesicle and nucleus, and inclosed in a thin smooth membrane. Upon this is laid the secretion of the albuminiparous gland, as the ova traverse that cavity in the *Pulmonata*; and they are coated and often connected together by analogous secretions in other orders of Gastropods; fecundation having previously taken place in the oviduct or uterus.

The ova of the marine Gastropods are enveloped, before exclusion, in mucous capsules, prepared by a special gland situated near the termination of the oviduct. The secretion in some species is soft, flexible, and transparent; in most it hardens by contact with the sea-water, and assumes various definite and characteristic forms: the nidus is sometimes simple, sometimes compound, but each compartment contains many ova; and the development of the embryo proceeds in the nidamental chamber until its own little defensive shell is acquired.*

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* CCCXXI.

In the terrestrial Gastropods the ova are usually spherical and opake, and separately extruded. Snails and slugs oviposit in the earth. The tropical *Bulini*† cement leaves of trees together to form an artificial nest for their large eggs.

The ova of the sea-slug (*Tritonia*) are expelled together in the form of a long thread, and are arranged in a spiral manner in the tenacious transparent covering of the thread. In the *Doris muricata* the ova are aggregated in a flattened spirally disposed albuminous band when excluded from the oviduct. The harder albuminous capsules which defend the ova of other marine Gastropods offer a great variety of forms, some of which are remarkable for their complexity, others for their symmetry and beauty. Here are displayed the nidamental sacs of the frail *Janthina*‡; they are of a flattened pyriform shape, composed of a delicate reticulate film of albumen, and are attached by one extremity to a float, formed likewise by a secretion of albuminous matter, dilated into a group of cells filled with air. To this float the parent *Janthina* commits her little progeny, and having securely fastened their several cradles or nursery cells, she detaches the float, which bears the ova to the surface, and sustains them where they may best receive the full influence of solar light and heat. The nidamental capsules of the *Pyrula rapa*§ are attached in regular linear series to portions of decayed wood; they are of a flattened sub-conical figure, adhere by their apex, and have their base emarginate. The nidamental capsules of the whelk‖ are common objects on our sea-shore; they are aggregated in large irregular masses, often attached to portions of oyster-shell; each capsule presents a depressed ovoid figure, with one side convex, the other flat or concave. The small nidamental cells of the Cowry (*Cyprea*) are aggregated in a flattened group. In the *Turbinella* the cells are of a flattened sub-pentagonal form, and adhere together, superimposed one upon the other, forming what is termed a camerated nidus. Each chamber contains between twenty and thirty embryos. In the preparation No. 2950, it may be observed that the rudimental shell is completely calcified and fitted to defend the little Gastropod before it emerges from the temporary shelter provided for it by the parent. Numerous other modifications of these secreted nests of the Gastropodous Mollusca might be enumerated.

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* CCCLXV. p. 84. pl. vi.

† Prep. 2943. B.

‡ See Preps. 2945, 2946.

§ See Prep. 2947. A.

‖ Preps. 2948. 2949.

The development of the Gastropods has hitherto been traced in a few apneustal, nudibranchiate, tectibranchiate, pulmonate, and pectinibranchiate species; and the results show considerable modifications in its course and phenomena. Most Gastropods are oviparous; some species of *Litorina* are ovo-viviparous: *Paludina* and *Clausilia ventricosa* are viviparous.

With the singular exception observed in Buccinum[*], in which the segmentar or granular germ-mass from which the embryo is developed results from a confluence of numerous, perhaps fifty, previously distinct minute germ-masses[†] in the nidamental capsule, that germ-mass is due to progressive segmentation of the yolk, the result of the usual multiplication of germ-cells which clothe themselves with the so-subdivided, but coherent, yolk substance. One cell in *Pulmonata* and *Aplysia*, indeed, is from the beginning conspicuously larger than the rest, and has been called the directive cell (richtungs blaschen, *fig.* 210, *a*). In all Gastropods the germ-mass takes the form of a long round embryo, one end of which becomes indented and clothed by ciliated epithelium, by which it rotates on its axis in the albumen of the egg. Sars[‡], who noted the oviposition of the *Tritonia Ascanii* on the 1st February, 1840, traced the segmentation of the yolk to the 8-fold division on the 4th day, and the completion of the germ-mass on the 8th day. The indentation producing the bilobed end of the embryo took place on the 15th day; after which the ciliated lobes extended outwards, and assumed the form of wings or "vela." Dr. Grant[§] had long before discovered the corresponding ciliated vela in the embryos of *Purpura*, *Trochus*, *Nerita*, *Doris*, and *Æolis*.

On the 20th day the rudiment of the foot appeared beneath the bases of the vela, and on the 22nd a transparent shell was developed which covered all the body save the ciliated vela and foot. "I could scarce believe my eyes," writes Sars, "when I made this discovery." As the body and shell enlarge and elongate, the cilia become stronger on the lobes, and the active movements of the embryos, crossing each other like midges in the clear albumen of the nidamental band, offer a most singular spectacle: the vela now move by muscular contraction alternately approximating and stretching outwards. On the hinder part of the foot is an operculum, which closes the mouth of the shell when the embryo retracts itself. Among the internal organs the acoustic capsules appear first, then the eyes. The tentacles next protrude, and the border of the mantle appears. The mouth is established between the vela. On the 36th day the stomach and a looped portion of intestine come into view out of the germ-mass, the remnant of which is chiefly changed in the hepatic and genital glands. A longitudinal muscle for retracting the body into the shell also now appears.

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[*] CCCLII.

[†] Called "ova" by the Authors of CCCLII., whose observations were, however, made on "ova" in the nidamental capsule, not in the oviduct of the female whelk, where the first effects of impregnation are to be traced.

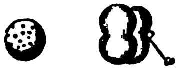
[‡] CCCLXVII.

[§] CCCLXXIV. p. 121.

During this course of development the nidamental band has become, by endosmose of sea-water, three times as thick as before. The albuminous substance is absorbed by the embryos: they respire by the reaction of their ciliated surface on the imbibed water; as they grow they, with difficulty, find room for their evolutions, and, between the 32nd and 38th days, rupture the delicate membrane of their nest, and struggle out. They are now about one-eighth of a line in length, and swim by ciliary action, the vela being kept stiffly outstretched. They survived in the vessels of daily renewed sea-water two weeks, then died, their embryo shells floating on the surface.

The ova of the *Aplysia* are excluded in a long string, enveloped by a transparent flexible mucus, in the centre of which they are aggregated in several irregular series. When examined at this period, the yolk has apparently divided itself into six, seven, or more numerous globules; or, in other words, as many germinal vesicles included in the same mass of albumen and in a common chorionic coat, have given origin to as many aggregations of vitelline cells; these, therefore, may be regarded as so many independent yolks, in each of which the same progressive fissiparous multiplications have been observed, as in the single vitellus of the ovum of the Planorbis, and of animals in general. *Fig.* 209. exhibits one of these yolklets prior to the commencement of the fissiparous action, by which subdivision of the mass is produced. *Fig.* 210. shows the quadrifid product of that action and of the assimilative powers of the resulting divisions. The directive cell is indicated by Van Beneden at *a*.*

209 210



Aplysia.

In *fig.* 211. the multiplication of the globules has increased, and two of them, of larger size than the rest, indicate, one, the seat of the future branchial organs, the other that of the muscular mass.

The ciliated epithelium, with which the vitellus is now almost

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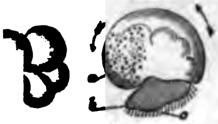
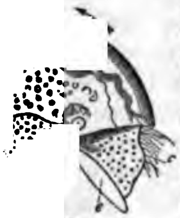
* CCCLXVIII. pl. 123. p. I.

11 212



Aplysia.

13



Aplysia.

ly covered, occasions the usual rotations of that body. The progress of transformation of this monad-like embryo to the Gastropodous form, resembles closely that which has been described in *Tritonia*. The remains of the vitelline mass (*fig.* 212, *a*), not yet metamorphosed into special organs, indicates the expanded alimen- sac; *b* is the apex of the rudimental foot, and *c* the velum with its ngly ciliated border. These parts protrude from a rudimental, , pellucid, and flexible shell, which covers all the rest of the sur- of the body. The arrows indicate the direction of the rotatory ements of the embryo, which now likewise describes its elliptical lutions in the chorionic cavity. As development proceeds and embryo increases in size, the shell acquires a more distinctly tur- ted form, and is slightly bent out of its vertical plane (*fig.* 213). An operculum (*e*) is formed upon the protruded surface of the foot: the course of internal development accords with that in *Tritonia*. The ciliated branchial surface (*c*) begins to be withdrawn more into the interior; and, in this state, protected completely by an external shell, the young Aplysia is launched into the ocean.

Truly may the subsequent growth, which effects an entirely internal position of the shell, with such a mutation of its form that the primitive nucleus can scarcely be detected upon the almost flattened plate now destined to protect the equally internal respiratory organs of the mature animal, justify us in applying to it the term metamorphosis. This term is still more applicable to the developmental phenomena in the Tritonia and Doris; since these Gastropods, which are not only naked, like the Aplysia, are devoid of any internal rudiment of a shell, and yet are provided with a delicate little operculated nautiloid horny external shell in their young state.

The same general course of development, in which the embryo or larval mollusk is provided with the ciliated lobes and operculated shell, has been traced by Lovén in *Æolis*, *Bulla*, *Cerithium**; by Nordmann† in *Tergipes*; by Allman‡ and Vogt§ in *Actæon*; by Lund‖ in *Murex* and *Natica*; by Carus¶ in *Paludina*, and by Siebold in *Vermetus*.** Rudiments of the vela are retained in *Tergipes*, *Æolis*, *Doris*, *Tritonia*, and *Aplysias*; and in *Thetys* they continue in almost their primitive form and proportions, unless the broad lobes of the adult be substituted for the embryonal vela, as is the case with the fins of the Pteropods; otherwise the little *Cymbulia* with its delicate symmetrical shell would represent a persistent embryo form of the higher Gastropodous *Encephala*. Prof. Muller* has detected ova and embryos of a Gastropod, which he believes to belong to a species of *Natica*, within the body of the *Synapta digitata:* they were contained in elongated sacs, firmly attached or fused at one end to the head, at the other end to the gut of the *Synapta*. The upper portion of the sac contains both spermatozoa (like those of *Natica*) and ova; the lower portion of the sac was intus-suscepted with a blind end, and this contained the ova with developed embryos, according to the velated type. This remarkable discovery indicates some singular parasitic habit in the generative economy of the mollusk (antè, p. 221.).

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* CCCLXIX. † CCCXL. ‡ CCCLXX. § CCCLXXI.

‖ CCCLXV. ¶ CCCLXXII. ** XXIV. p. 360.

The development of the pulmonated Gastropods proceeds without any such metamorphosis as that above described. In the testaceous species its course has been ably traced by Prevost and Dumortier† in *Limnæus*, by Pfeiffer‡ in *Helix*, and by Jacquemin and Quatrefages in *Planorbis*.§

The transparency of the albuminous capsules of the ova, and of the ova themselves in the fresh-water Pulmonata, renders them beautiful and favourable objects for such researches.

In the *Physa*, the nidamental mass is short and ovate: in the *Limnæus* it is oblong, and not striated, as in the *Planorbis*. The double movement of the embryo is more conspicuous in the *Limnæus* than in the *Planorbis*. The first movement of the yolk is one of rotation upon its axis; but, as development proceeds and the ciliary vibrations are strengthened, the embryo begins to travel in an elliptical course around the interior of the egg; its two movements (to compare small things with great) resembling those of the planets in the solar system.

In the *Planorbis* the single centre of the ovum, or the germinal vesicle with its nucleus, is very evident in the ovarian ovum. The processes which lead to the disappearance of the vesicle, take place in the oviducal pouch called the "matrix." The transparent nidamentum in which the ova are excluded is shield-shaped and striated; it is not attached to any foreign body but falls to the bottom. After the usual subdivisions of the yolk, a group of less opake cells makes its appearance in a particular part of the periphery of the granular mass; and an epithelial membrane begins to spread over its surface, from which cilia are soon developed. Their action begins about the third day to affect the surrounding albumen, and afterwards to rotate the embryo itself. The embryo now elongates: its hinder end assumes a spiral form. The aggregation of stronger and more numerous cilia on a particular part of the surface of the yolk indicates the seat of the development of the respiratory organs. Two groups of extremely minute and compact cells, covered by a thicker epithelium, project from two other parts of the surface, and constitute the rudiments of the head and foot. The centre of the yolk presents the form of larger and less regular globules, which indicate the position of the wide digestive sac. The rudiments of the head and foot are sufficiently obvious on the fifth or sixth day; the acoustic capsules appear: the respiratory organs are formed on the sixth or eighth day, according to the warmth of the weather. On the eighth day the characteristic tentacles begin to sprout from the rudimental head. On the tenth day all that spirally disposed part of the embryo which is not occupied by the head, the foot, and the breathing organ, is covered by a thin and transparent pellicle, which is the rudiment of the shell. On the eleventh day one of the large central globules of the yolk begins to distinguish itself from the alimentary mass by feeble contractions and dilatations, of which about sixty may be counted in a minute: this is the heart. The mouth can now be discerned, and the small eyespecks appear like black granules at the base of the tentacula. On the twelfth day the embryo moves by its own contractions independently of the rotation produced by the cilia. On the thirteenth day acts of deglutition are discernible; the embryo swallows the remaining albumen, the anus is completed, and the genital organs begin to be formed. On the fourteenth day the young *Planorbis* ruptures by more violent contractions the chorion, and escapes into the water, protected by its own flexible shell.

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* CLXX. † CCCLXVI. ‡ CCCLXXV. § CCCLXXVI.

The course of development is different in the naked *Pulmonata*. In the month of February Van Beneden and Windischmann[*] found ova of a slug (*Limax agrestis*) buried in groups. They are laid in autumn and remain until spring, resisting the cold that kills the adults. At the beginning of spring the germ and embryo may be found in all stages of development. The egg, when laid, has an external lamellated nidamental membrane; a thin chorion inclosing the albumen; a vitelline membrane with a twisted filamentary appendage; and the vitellus, which is small as compared to the albumen.

Two clear germ-cells rise from the centre of the vitellus and pass to its periphery: their existence is followed by the first fission of

[*] CCCLIV.

yolk; successive cleavage reduces it to the mulberry state; and the subdivision proceeds to such a degree of minuteness, that the yolk seems to have returned to its primitive condition: it is now the germ-mass.

These divisions and subdivisions take place rapidly under the eyes of the observer. By compression the hyaline centres escape from the yolk-segments or germ-cells. A vibratory movement of the germ-mass gives the first intimation of the ciliated epithelium, which, as it is perfected, effects a rotation of that body: this movement is increased by warmth and checked by cold. There next is seen a thickening of the integument, with a development of two tubercles; one of these enlarges and remains above the germ-mass, representing the mantle and visceral cavity; the other elongates, represents the foot or basis of the embryo, grows quickly, and soon acquires a cavity with fluid: then a bud grows from its hinder part, which also becomes a vesicle. This "caudal vesicle" grows to one-third the size of the rest of the embryo, and contracts so as to drive its contents into the cavity of the embryo, which, in turn contracting, sends the fluid back to the caudal vesicle. Sometimes the caudal vesicle contracts twice before the embryo-sac reciprocates. The liquid so oscillating contains spherical vesicles like blood-discs. "Trabeculæ" next appear in the caudal vesicle, which seems a mere appendix to the embryo. The cilia upon the caudal vesicle and tentacles are very small compared with those of the Aplysia.

With the caudal appendage appears the fissure indicative of the anterior border of the foot; and in advance of this, a lobe which soon becomes bifid, and forms two tentacles. Above the foot the subœsophageal ganglion is developed. A crystal of carbonate of lime is the first rudiment of the shell, and is deposited in the substance of the skin, above the visceral cavity. The cephalic lobe proceeds to divide into the upper or ocular pair, the second pair of tentacles, and a lower pair of processes forming the sides of the mouth.

The embryo-sac now becomes pyriform, and is pressed between the advancing head and the shield; it next elongates and enters the body; the intestine begins to appear, and the germ-cells may be distinctly seen to pass to and fro into it, by a movement like that which took place between the embryo-sac and the caudal vesicle.

The third period of development is marked by the appearance of the heart, by the disappearance of the caudal vesicle, by the completion of the digestive canal, and by the total intus-susception of the unconverted germ-mass.

The rudimentary shell or shield is pushed backwards: the heart is plainly indicated by its pulsations under the shield, before its contour

e clearly seen. Next, the auricle and ventricle are formed by a
triction of the pulsating tube ; afterwards the pericardium and
vessels are visible. The globules in the fluid sent into the body
the caudal vesicle go towards the heart. The embryo slug has
an extensile proboscis, which is formed by the lobes below the
cles, and which afterwards disappears. A peculiar glandular
attached to the parietes of the embryo-sac is compared to the
sitory kidney, or Wolffian body in the vertebrate embryo. At a
distance from the anus there projects a cæcum, which after-
s becomes the urinary sac. The nervous system is at first a
lar ring containing fluid ; it then swells out into the super- and
-œsophageal masses, and gets neurine in the interior of the sheath.
e acoustic vesicles appear above the subœsophageal mass.

The ocular tentacles appear for a long time as rounded and later-
y compressed fins, by the side of the vitelline sac ; they may be
homologues of the vela of the pectinibranchiate embryos.

The caudal vesicle disappears before the young is excluded from
egg ; its contractions go on after those of the heart have begun ;
nd thus there are two currents, one of blood in vessels through the
iscera, and the other of fluid outside of and bathing the viscera.

The pulmonary sac is formed by a simple depression at first, which deepens as the heart and vessels become developed, and the vascular network spreads over its inner surface. The generative organs are formed after exclusion.

Class PTEROPODA.

Encephalous mollusks, with wing-like fins from the sides of the head or neck.

Order THECOSOMATA.

With an external shell : head indistinct.

Family *Hyaleidæ*. Shell symmetrical.
Genera *Hyalea, Cleodora, Cuvieria, Eurybia, Cymbulia, Tiedemannia.*

Family *Limacinidæ*. Shell spiral.
Genera *Limacina, Spirialis, Cheletropis.*

Order GYMNOSOMATA.

Without a shell : head distinct : fins attached to the neck.

Family *Cliidæ*.
Genera *Clio, Pneumodermon, Pelagia, Cymodocea.*

Class GASTROPODA.

Encephalous mollusks, with a locomotive ventral disc, or foot.

A. *MONŒCIA.*

Order APNEUSTA.

No distinct respiratory organs: no shell.
Genera *Actæon, Rhodope, Zephyrina, Tergipes, Eolidina, Æolis.*

Order NUDIBRANCHIATA.

Branchiæ extending more or less freely from various parts of the body.
Genera *Scyllæa, Tritonia, Doris, Thetis, Polycera.*

Order INFEROBRANCHIATA.

Branchiæ at the lower part of the sides of the body, between the foot and mantle.
Genera *Phyllidia, Diphyllidia, Ancylus.*

Order TECTIBRANCHIATA.

Branchiæ covered by the shell or mantle: a shell in most. Androgynous.
Genera *Tornatella, Bulla, Bullæa, Doridium, Gastropteron, Aplysia, Dolabella, Notarchus, Icarus, Lobiger, Pleurobranchus, Umbrella.*

Order PULMONATA.

Part of the mantle-cavity forming a vascular air-sac or lung.

Family *Helicidæ.* Shell external, usually well developed, closed by an epiphragm during hybernation.
Genera *Helix, Vitrina, Succinea, Bulinus, Achatina, Pupa, Clausilia.*

Family *Limacidæ.* Shell rudimental, internal.
Genera *Limax, Arion, Parmacella, Testacella.*

Family *Oncidiadæ.* No shell.
Genera *Oncidium, Vaginulus.*

Family *Limneidæ.* Shell thin, horn-like, well developed.
Genera *Limnea, Physa, Ancylus, Planorbis.*

Family *Auriculidæ.* Shell with a horny epidermis.
Genera *Auricula, Conovulus, Carychium.*

mily *Cyclostomidæ.* Shell with an operculum.
Genera *Cyclostoma, Pupina, Helicina.*

'amily *Aciculidæ.* Shell elongated, cylindrical, with a subspiral rculum.
Genera *Acicula, Geomelania.*

B. *DIŒCIA.*

Order Nucleobranchiata.

Branchiæ, when distinct, packed in small compass with the heart a dorsal mantle cavity, or in a small symmetrical shell; sometimes nting together with the shell. Foot rudimental.

Family *Firolidæ.* A small branchial shell, or none.
Genera *Firola, Carinaria, Cardiapoda.*

Family *Atlantidæ.* A body-shell.
Genera *Atlanta, Porcellia, Bellerophon, Cyrtolites.*

Order Tubulibranchiata.

Animals inclosed, with their branchiæ, in long, curved, or flexuous shelly tubes.
Genera *Vermetus, Dentalium, Magilus.*

Order Cyclobranchiata.

Branchiæ usually a series of lamellæ surrounding the body between the foot and mantle.

Family *Patellidæ.* Shell with the apex turned forwards.
Genera *Patella, Acmæa, Gadinia.*

Family *Chitonidæ.* Shell subdivided into eight pieces.
Genera *Chiton, Chitonellus, Acanthopleura.*

Order Scutibranchiata.

Branchiæ protected by a simple or shield-shaped shell.

Family *Halyotidæ.* Shell with the outer lip notched or perforated.
Genera *Haliotis, Scissurella, Pleurotomaria.*

Family *Fissurellidæ.* Shell limpet-shaped, perforated at the apex, or notched anteriorly.
Genera *Fissurella, Emarginula, Parmophorus.*

Order Pectinibranchiata.

Branchiæ pectinated or comb-shaped; in a special cavity at the fore part of the back. Sexes distinct.

A. *Holostomata.* Margin of the shell-aperture entire.

Family *Cupuloidæ.* Shell limpet-shaped, with the apex subspiral.

Genera *Pileopsis, Hipponyx, Crepidula, Calyptræa, Lithedaphus.*

Family *Turbinidæ.* In the following families the shell is spiral and pyramidal, or turbinated.

Genera *Turbo, Phasianella, Trochus, Monodonta, Delphinula, Euomphalus, Stomatella, Broderipia.*

Family *Neritidæ.*

Genera *Nerita, Pileolus, Neritina, Navicella.*

Family *Paludinidæ.*

Genera *Paludina, Ampullaria, Valvata, Janthina.*

Family *Litorinidæ.*

Genera *Litorina, Solarium, Litiopa, Rissoa.*

Family *Turritellidæ.*

Genera *Turritella, Vermetus, Scalaria.*

Family *Melaniadæ.*

Genera *Melania, Paludomus, Melanopsis.*

Family *Cerithiadæ.*

Genera *Cerithium, Potamides, Nerinæa, Struthiolaria.*

Family *Pyramidellidæ.*

Genera *Pyramidella, Stylina, Macrocheilus.*

Family *Naticidæ.*

Genera *Natica, Sigaretus, Velatina.*

B. *Siphonostomata.* Margin of the shell-aperture notched or produced into a canal.

Family *Cypræidæ.*

Genera, *Cypræa, Erato, Ovulum.*

Family *Volutidæ.*

Genera *Voluta, Oliva, Cymba, Mitra, Valvaria, Marginella.*

Family *Conidæ.*

Genera *Conus, Pleurotoma.*

Family *Buccinidæ.*

Genera *Buccinum, Harpa, Cassis, Purpura, Eburnea, Terebra, Nassa, Monoceros, Dolium.*

Family *Muricidæ.*

Genera *Murex, Ranella, Triton, Fasciolaria, Turbinella, Cancellaria, Pyrula, Fusus.*

Family *Strombidæ.*

Genera *Strombus, Pteroceras, Rostellaria.*

LECTURE XXIII.

CEPHALOPODA.

trace the progressive diminution of the existing species of Gas- odous Mollusca by their fossil shells through the descending ta of the tertiary periods of geology, beyond which such indi- ons become very doubtful and obscure.* In the oldest tertiary osits, not more than 3½ per cent. of the remains of any class of ollusca have been identified with species now living. From this t, which indicates the dawn of the existing state of the testaceous ına, the term "eocene" is applied to these strata: in the superim- posed or "miocene" tertiary beds there are about 17 per cent. of fossil lls, identical with recent species; in the deposits of a third or liocene" era from 35 to 40 per cent.; and, in still more modern 'pleistocene" formations, the older tertiary shells have almost dis- ppeared, and the number of species identical with those now living is from 90 to 95 per cent.

Amongst the shells which characterise the eocene strata, there are four or five of symmetrical figure, divided into chambers, which are perforated by a tube or siphon, like the existing large Nautilus and the little Spirula; but they belong to species which are unknown in modern seas. In the secondary formations, which succeed the eocene in depth and order of antiquity, the chambered siphoniferous shells become more numerous and diversified; they depart further from the two remaining recent types, and manifest a rich variety of form and structure. From these modifications of the shells we not only infer corresponding differences in the habits of their extinct occupants, but we can trace, in some instances, the nature of the associated differences in the organisation of the soft parts.

The vast number of the complex shells known by the names of Ammonites, Orthoceratites, Hamites, Baculites, Turrilites, Belemnites, &c., and the constancy which particular genera and species manifest in their relations to particular strata, indicate that the functions which their molluscous fabricators performed in the organic economy of the ancient world must have been equal and closely analogous to those which have since been assigned to the Pectinibranchiate Gastropods that have superseded them in the seas of the tertiary and existing epochs.

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* The supposed recent species of *Trochus* observed by Defrance in chalk, and the *Paludina* and *Cyclas*, described by Dr. Fitton from the Wealden, are not considered to be identical with existing species by Deshayes and Lyell.

What, then, were the nature and affinities of the extinct constructors of those ancient chambered siphoniferous shells? Earnestly and repeatedly had this question been pressed upon the attention of zoologists and comparative anatomists, and long was it before any satisfactory reply could be returned. The *Nautilus Pompilius* and *Spirula australis*, the representatives in the existing seas of that vast assemblage of siphoniferous Mollusks which peopled the ocean during the secondary epochs, could alone yield the requisite data for its determination, and for a long period comparative anatomists were disappointed in their demands for these most rare and coveted subjects. In fact, until the year 1832, geologists could be supplied only with conclusions based upon more or less probable analogies and conjectures. Before this period, only one account of the *Nautilus Pompilius* was extant, in the work of Rumphius*, a Dutch naturalist of the 17th century, whose figure of the animal was pronounced by Cuvier†, the profoundest malacologist of his age, to be unintelligible ('indechiffrable'). The little light that it might have thrown upon the interesting question of the affinities of the Nautilus was obscured by the grotesque, and, as they have since proved to be, fictitious figures of the animal, subsequently published by De Montfort‡ and Dr. Shaw§, and the evidence of Rumphius seems to have been rejected by the naturalists of the French circumnavigatory expedition under Captain Freycinet, who, on their return in 1881, published a description and figures of part of an unknown molluscous animal, presumed to be that of the *Nautilus Pompilius*‖; and which, had their conjecture been verified, would have indicated the chambered shell of the Nautilus to have been an appendage to some huge heteropod, allied to the Carinaria.

If the claims of the Ammonite and its extinct congeners to take rank in a higher class of Mollusca, had appeared to some zoologists to be established by the figure of the animal of the *Spirula*, published by Péron¶, it might, at the period to which I allude, have been objected that this evidence, likewise, had been invalidated by Fremenville's assertion to Brongniart, cited by De Blanville**, that the animal of the Spirula was wholly different from Péron's description of it.

If an appeal had been made from the unsatisfactory and conflicting evidence derivable from the existing chambered siphoniferous shells to the simple univalve of the *Argonauta*, which resembles them in its symmetrical figure, it might, on the one hand, have been objected that the correspondence of outward form alone, without the camerated and siphonated structure, was insufficient to support the conclusion of the cephalopodic nature of the *Nautilus* or *Spirula*, since the shell of the *Carinaria* might have been adduced as much more closely resembling that of the *Argonauta*; and, on the other hand, the scepticism of the majority of conchologists at that period, as to the Argonaut shell being actually fabricated by the Cephalopod usually found in it, might have been adduced to show how little value could be attached to the superficial resemblance between the Argonaut shell and that of the Nautilus, in the determination of the Cephalopodic character of the constructor of the latter; and, by inference, of those of the allied extinct chambered shells. Most acceptable, therefore, at this conjuncture, was the arrival of the molluscous inhabitant of the *Nautilus Pompilius*.

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* CCCLXXXII. † XII. tom. iii. p. 18. ‡ CCCLXXXIII.
§ CCCLXXXIV. ‖ CCCLXXXV. ¶ CCCLXXXVI.
** CCCXXVII. t. i. p. 381., 8vo. 1825. Nouvelles Annales du Muséum, t. iii. p. 20. 4to. 1834.

The long-sought-for animal was captured in the South Seas by Mr. George Bennett, a member of the Royal College of Surgeons, and by him presented to the museum of the college: it was entrusted to me to be anatomised, and my description with illustrations was liberally published by the Council.*

The dissection of this unique specimen established the claims of the *Nautilus Pompilius* to rank in the highest class of Mollusca, and at the same time brought to light so many important modifications in the cephalopodic type of structure as to necessitate the establishment of a new order for its reception. The present Lecture will be devoted to the demonstration of the principal organic characters of this order, which is called *Tetrabranchiata*, and to a brief review of the extinct chambered siphoniferous shells, and of their relations to the existing Cephalopods.

The soft parts of the pearly Nautilus (*fig.* 214.) form an oblong mass divided by an irregular transverse constriction into two nearly equal segments; the posterior is smoothly rounded, soft, and membranous, containing the viscera, and adapted to the last chamber of the shell; the anterior is densely muscular, and includes the organs of sense and locomotion.

The mantle is very thin upon the posterior part of the body; it is continued backwards in the form of a slender tube, which penetrates the calcareous siphon (*c*), in the septum closing the occupied chamber behind, and is thence continued, as the membranous siphon (*d*) through all the other divisions of the shell to the central nucleus. As the mantle advances towards the anterior part of the abdomen, it in-

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* CCCLXXXVII.

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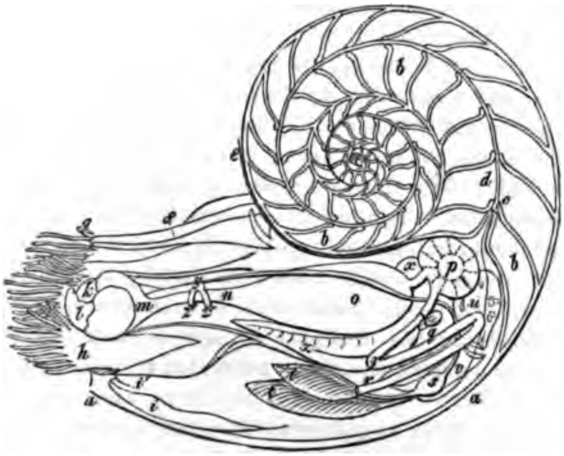

Nautilus Pompilius.

creases in thickness, becomes more muscular, and extends freely outwards, forming a wide concave fold on the dorsal aspect (*e*), which is reflected over the black-stained involuted convexity of the shell. The margin or collar of the mantle is continued downwards and forwards on each side with a sinuous outline, and is perforated below for the passage of the muscular expiratory and excretory tube called the funnel (*i*). Besides the muscularity of the free border of the mantle, which indicates its power of extension and contraction, its surface is studded with the orifices of many minute glandular crypts; and it is the organ by which the growth of the shell is principally effected. The nidamental glands form, in the female, two circular convexities on the ventral surface of the abdomen, behind which the mantle is encircled by a thin layer of brown matter, like the periostracum, which band is very narrow above and below, but expands on each side into a broad plate, corresponding in size and form with the surfaces of attachment of the two great muscles for adhesion to the shell.

The anterior or muscular division of the Nautilus, which may be termed the head, forms a strong and wide sheath, containing the mouth and its more immediate appendages; its inner surface is for the most part smooth, the outer one divided and extended into many parts or processes. The chief of these forms a broad triangular muscular plate or hood (*f*), covering the upper part of the head, and presenting a middle and two lateral superficies; the former being traversed by a median longitudinal furrow, indicating the place of confluence of the two large hollow tentaculiferous processes of which it is composed. The back part of the hood is excavated for the lodgment of the involuted convexity of the shell, and the above-described fold of the mantle covering it. Each side of the head supports a group of perforated processes or digitations, the largest of which is next the hood, and the rest decrease in size as they descend in position. Exclusive of the short subocular, perforated process*, the digitations are eighteen in number on each side disposed irregularly, but all directed forwards, some not reaching as far as the anterior margin of the head, others projecting a few lines beyond it. They are of a conical, subtriedral form: the large one next the confluent pair which forms the hood, has, like that part, a papillose outer surface. Each process contains a long and finely annulated tentacle (*g*), of a subtriedral form, with the inner surface incised, as it were, by deeper and fewer cuts (*fig.* 216, *e*), so as to present the appearance of a number of close-set transverse plates, slightly indented by a median longitudinal impression (ib. *f*). This modification must increase the prehensile and sentient properties of the inner surface of the tentacle, and it is on the corresponding part of the larger and fewer tentacles of the dibranchiate cephalopods that the acetabula are developed. The angle between the two outer finely annulated surfaces subsides near the end of the tentacle, which thus becomes flattened.

To the nineteen tentacula which are supported by the confluent and free digitations on each side of the head, two others must be added, which project from very short sheaths, one before, the other behind, the eye; the lateral transverse incisions are deeper in these than in the digital tentacles. The eyes are about the size of hazel nuts, and are attached each by a short peduncle to the side of the head, behind the digitations, and a little below the margin of the hood. The inferior surface of the oral sheath is excavated for the lodgment of the infundibulum.

The mouth is armed with two mandibles, shaped, as in other cephalopods, like the beak of a parrot reversed, the lower mandible (*fig.* 214, *l*) overlapping and curving upwards beyond the upper one (*k*). Both mandibles are horny, with their tips encased by dense calcareous matter, and their base implanted in the thick muscular parietes of the mouth.

They are immediately surrounded by a circular fleshy lip with a plicated anterior border, external to which there are four broad flattened processes called "labial," continued forwards from the inner surface of the oral sheath, two of which are superior, posterior, and external, the other two (*h*) are inferior, anterior, and more immediately embracing the mouth: the latter are connected together along their inferior margins by a middle lobe, the inner surface of which supports a series of longitudinal lamellæ. On the inner surface of the oral sheath beneath these processes there are two clusters of soft conical papillæ, and on each side of these a group of lamellæ. Each of the four labial processes is pierced by twelve canals, the orifices of which project in the form of short tubes from the anterior margin, and each canal contains a tentacle similar to, but smaller than, those of the digitations. Thus the number of tentacles with which the pearly Nautilus is provided, amounts to not less than ninety, of which thirty-eight may be termed digital, four ophthalmic, and forty-eight labial. In the second specimen of this rare molluscous animal, presented to the college by Captain Sir Edward Belcher*, there was a slight difference in number in the digital tentacula of the two sides, nineteen being on the right, and seventeen on the left side. The labial processes in the specimen of Nautilus described by M. Valenciennes contained thirteen tentacles instead of twelve; and some variation is not surprising in the number of prehensile organs developed in such unwonted profusion in the Nautilus. A more marked modification of the labial processes has been found in a male specimen†, which is probably sexual, and will be subsequently described.

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* Particularly described and shown not to be tentaculiferous by M. Valenciennes, CCCLXXXVIII.

The skeleton of the Nautilus consists of two parts, equally distinct in their position, texture, and organic properties: the one is the external chambered shell; the other is a rudimental cartilaginous cranium, which sends out processes for the attachment of the principal muscular masses. The shell of the Nautilus consists of an elongated sub-compressed cone, convoluted in close spiral whorls, upon the same plane, so as to be perfectly symmetrical. In the full grown mollusk, three-fourths of the shell from the commencement no longer serve to lodge the animal, but have been partitioned off as they have been progressively evacuated, into a number of chambers (*fig.* 214, *b*, *b*), increasing regularly and gradually in size from the first to the last, or to the last but one. The open chamber *a a*, which contains the animal, is much larger than the rest, slightly curved, concave behind and on the ventral aspect, and divided into two concavities on the dorsal aspect, by the projecting convoluted spire. At the sides are two slight impressions of the large lateral muscles and those of the connecting narrow cincture, and, posteriorly the infundibular aperture of the calcareous siphon is seen at the middle of the last septum. This calcareous tube extends about one fourth of the way towards the succeeding septum, which, with all the others, is similarly perforated and prolonged backwards near their middle part. The septa, about thirty-five in number, are concave towards the aperture of the shell, except below, where they are convex transversely; for their circumference does not follow precisely the transverse section of the spiral cone, but describes a slightly sinuous outline. The shell consists of two substances; the outer one opake, white, or stained with the characteristic red-brown stripes; the internal layer is twice as thick as the former, and of a nacreous structure and lustre: the external surface of the shell is naturally covered with a reddish brown or greenish epiderm or periostracum; and upon the involuted convexity of the shell, the dorsal fold of the mantle deposits a thin plate of a nacreous texture, stained externally of a deep black colour, which can be traced as an extremely thin additional layer along the interior whorls of the shell. In the *Nautilus Pompilius* the hole or umbilicus, at the extremities of the imaginary axis round which the involutions of the shell have been made, is filled up by the deposition of semi-nacreous material: but in the species or variety termed *Nautilus umbilicatus*, the margins of the dorsal fold of the mantle are not developed to the same extent, and the umbilicus continues open. The septa consist exclusively of the nacreous substance: they are thinnest at their margins, which, from their oblique applications to the wall of the shell, increase its thickness at the line of contact. The chambers are lined by a thin membranous pellicle, thrown off by the mantle when the animal was in the act of advancing forwards to enlarge its shell and form a new septum.

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* CCCLXXXIX.

† CCCXC.

The internal cartilaginous skeleton of the Nautilus is confined to the inferior surface of the head: no part of it extends above the œsophagus. Viewed sideways, it presents a triangular form; a portion of the annular brain is protected by a groove on the upper surface of the cartilage: two strong processes are continued from its anterior and superior angles into the crura of the infundibulum, giving origin to the chief muscles of that part. Two other thinner processes are continued backwards, and curve inwards and downwards; they give origin to the two great muscles which pass from the internal to the external skeleton, or, in other words, attach the animal to the shell.

The muscular fibres of the head or oral sheath arise from the whole of the anterior or outer part of the internal skeleton. The muscular structure of the funnel presents a much greater development than in the naked Cephalopods; and, from its relation to those masses which, on the one hand, attach the soft parts to the shell, and, on the other, connect the head to the body, we may conclude that the funnel is the principal organ of natation, and that the Nautilus is propelled, like the Octopus, by a succession of jerks occasioned by the reaction of the respiratory currents upon the surrounding water. The orifice of the funnel is guarded by a valve (*fig.* 214, *i'*).

The retraction of the tentacula is done by longitudinal fibres, the elongation by transverse ones. These are not, however, disposed in circular or spiral series, so as to attenuate and lengthen the tentacle by a general compression, but present a more complex disposition by which they diminish the transverse diameter without compressing the central nerve. The transverse fibres (*fig.* 216, *a*) arise in numerous and distinct fasciculi from the dense cellular tissue (*b*), surrounding the nerve in the centre of the tentacle (*d*), and radiate at equal distances to the circumference; they divide and subdivide as they diverge, and also send off lateral fibres, which form a delicate network in the interspaces of the rays, especially at the angles : the meshes include the longitudinal fasciculi, the cut ends of which are shown at *c*.

The mechanical arrangement of the contractile fibres is very similar to that of the complex muscles described by Cuvier in the proboscis of the elephant. The attenuation and elongation of this brobdignagian tentacle must be effected without compressing the central breathing tubes, and transverse fibres accordingly radiate from the dense ligamentous tissue which surrounds them : the same prospective contrivance is manifested to prevent the compression of the nerves and vessels in the muscular system of the ninety proboscides of the Nautilus.

For the special account of the myology of the Nautilus, which includes the muscles of the oral sheath and its digitations, of the labial processes and mouth, and of the infundibulum, those for adhesion to the shell, those of the mantle, those of the tongue, the fibres of the tunic inclosing the liver and stomach, and the muscles of the organic system, I must refer to the published monographs on the anatomy of this animal.*

The principal masses of the nervous system of the Pearly Nautilus (*fig.* 215.) are concentrated in the head. The super-œsophageal part, or brain (*a*), presents the form of a short, thick, transverse, round chord or commissure, connected at each extremity with three ganglionic masses. The middle and superior of these (*b*) supplies the eye and the inferior hollow tentaculiform organ: the anterior and inferior ganglion (*c*) meets its fellow below the œsophagus: the posterior ganglion (*d*), in like manner, joins that of the opposite side and forms a second and posterior œsophageal ring. The nerves given off immediately from the super-œsophageal mass supply the muscular and other parts of the mouth, and have small pharyngeal ganglions developed upon them. The anterior œsophageal ring gives off principally the nerves to the tentacula (*f*, *f*), and the two median ones (*g*) are connected with a ganglion (*h*), which supplies the tentacula of the inferior labial processes and the lamellated organs on that part of the oral sheath. The tentacular nerves are continued, like those of the arms in the higher Cephalopods, along the middle of the tentacle, attached by loose cellular tissue to the vessels of the part. The posterior collar gives off numerous nerves (*m*) of a flattened form, which supply the muscles of the shell. The respiratory nerves form a small ganglion (*q*) at the base of each pair of gills, from which branches are sent to those organs, to the heart, and to the appendages of the veins. A plexus of more delicate visceral nerves (*r*) is continued backward along the interspace of the branchial nerves, and the chief branches are connected with a small ganglion situated between the cardiac and pyloric orifices of the stomach. The posterior subœsophageal nervous mass combines the homologues of both the branchial and pedial ganglions in the inferior Mollusca: the anterior ring answers to the ganglia in the higher Cephalopods, called "pes anserinus" by Cuvier: the ophthalmic tentacula, which derive their nerves (*n*, *n*) close to the origin of the optic ganglion, may be considered as homologous to the four tentacula in the Aplysia. The hollow plicated process beneath the eye, which Valenciennes regards as the olfactory organ, likewise receives its nerves from the extremity of the super-œsophageal chord. Three small nervous filaments, described by the same author as passing from the extremity of the super-œsophageal chord to the adjoining part of the cephalic

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* CCCLXXXVII. & CCCLXXXVIII.

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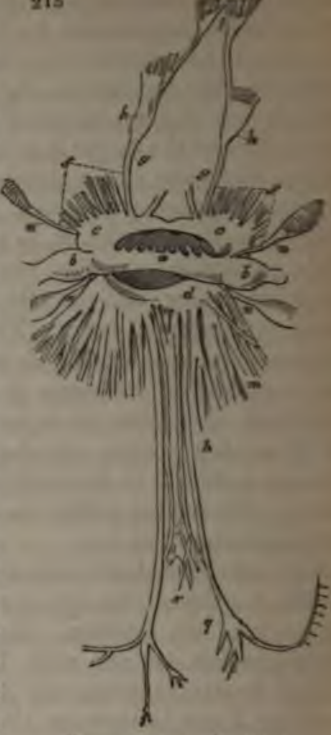

Nervous System. Nautilus.

cartilage, he considers as acoustic nerves; but these nerves are given off from the sub-œsophageal ganglion in the higher Cephalopods, and in all the Gastropods, in which the organ of hearing has been observed.

The eyes, as before stated, are attached each by a short pedicle to the side of the head, over-arched by the projecting margin of the hood. The form of the ball is sub-hemispherical, being flattened anteriorly along its inferior border, there is a slightly elevated ridge, from which a smaller ridge is continued to the middle of the anterior surface of the eye, which is perforated by a round pupillary aperture, about a line in diameter. The sclerotic tunic, which is a tough, ligamentous membrane, is thickest posteriorly, and becomes gradually thinner to the margin of the pupil. The optic filaments form a pulpy mass at the floor of the eye, from which the retinal expansion is continued as far forwards as the semidiameter of the globe: it is lined, like the rest of the interior of the eye, by a thick black pigment, which is doubtless perforated by the retinal papillæ, or otherwise a perception of light must take place in a manner incompatible with our knowledge of the ordinary mode in which the retina is effected by luminous rays. The crystalline lens was not present in the specimen dissected by me, and M. Valenciennes states that he was unable to observe any of the humours of the eye.[*] In the *Nautilus umbilicatus*, Mr. Macdonald found "a mere viscous matter protecting the retina from the sea-water."

The cavity in the cephalic cartilage, apparently that described in my Memoir [†] as containing a sinus of the cephalic veins, but which M. Valenciennes regards as the organ of hearing, is defective in the structures which the uniform analogy of that organ in the molluscous subkingdom leads us to conclude are essential to it: there were no traces, for example, of otolithes.[‡] In the *Naut. umbilicatus* there are "two spheroidal acoustic capsules placed one on each side, at the union of the supra- and sub-œsophageal ganglia, and measuring each about $\frac{1}{12}$th of an inch in diameter. Each capsule rests internally against the nervous mass, and is received on its outer side into a little depression in the cephalic cartilage. It is enveloped in a kind of fibrous tissue, and filled with a cretaceous pulp, consisting of minute otoconial particles, varying much in size, and sometimes combined in stellate cruciform or other figures."[§]

With respect to the organ of smell, the structure and position of the soft close-set membranous lamellæ at the lower and inner part of the oral sheath immediately in front of the mouth, appeared to me to manifest the conditions of the olfactory organ more obviously than do those short hollow internally lamellated processes which project from the outside of the head beneath the eyes. If, however, the cavity with tumid margins, opening near the eye of the higher Cephalopods, be actually, as Kölliker conjectures*, the olfactory organ, Valenciennes' idea of the sub-ocular hollow processes may be the true one.

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[*] Loc. cit. p. 289.

[†] CCCLXXXVII. p. 16.

[‡] "Elle ètait remplie d'une pulpe homogène" (coagulated blood?), "et ne contenait aucune sorte de concrétions."—Loc. cit. p. 291. Siebold suggests (xxiv. p. 384.), that the otolithes may have been originally uncalcified, as in *Eledone*, and have become dissolved.

[§] CCCCVII. p. 312.

The complex and well developed tongue of the pearly Nautilus exhibits in the papillæ of its anterior lobes and in the soft ridges of its root, the requisite structure for the exercise of some degree of taste.

The papillæ upon the exterior surface of the two large confluent digital processes forming the hood and of the two digitations next in size immediately beneath them, form a remarkable character in the Nautilus, on account of their obvious similarity to tactile papillæ; but the sense of touch must be specially exercised by the numerous cephalic tentacles, which from their softness of texture, and especially their laminated inner surface (*fig*. 216, *e*, *f*), are to be regarded as organs of exploration not less than as instruments of prehension.

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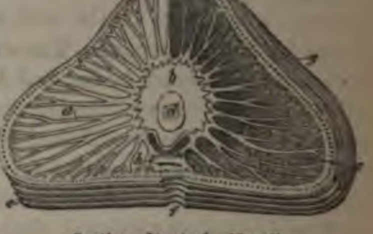

Section of tentacle, Nautilus.

The calcareous extremity of the upper mandible is sharp-pointed and solid to the extent of five lines. The lower mandible is sheathed with a thinner layer of the hard white substance, which forms a dentated margin. The fossils termed "rhyncholites," are the homologues of these calcareous extremities of the beak in cognate extinct cephalopods. The muscular subspherical mass, which supports and moves the mandibles, is provided with four retractors, and can be protruded by a strong semicircular muscle, which is continued from the margin of one of the inferior labial processes over the mandibles and their retractor muscles to the labial process of the opposite side.

The tongue is supported by a horny, slightly curved, and transversely striated plate. The fleshy substance of the tongue forms three distinct papillose caruncles anteriorly, into which the retractor muscles are inserted. The dorsum of the tongue is incased by a thin layer of horny matter, supporting four longitudinal rows of recurved spines; behind which the surface is again soft and papillose. Two broad duplicatures of mucous membrane project forwards from the sides of the pharynx; they each include a simple layer of salivary follicles, the secretion of which escapes by a single perforation in the middle of the process.

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* CCCXCI. p. 107.

The lining membrane of the pharynx is disposed in numerous longitudinal folds, where it begins to contract into the œsophagus. This tube, having passed through the nervous collar, dilates into a capacious crop, from the bottom of which a contracted canal, half an inch in length, is continued to an oval gizzard. The intestine commences near the cardiac orifice, and soon communicates with a small round laminated pouch, through which the biliary secretion passes to the intestine. This canal forms two abrupt inflections, and terminates in the branchial cavity near the base of the funnel close to the proboscidian end of the oviduct.

The epithelium of the œsophagus and ingluvies is developed into a thick cuticular membrane with minute ridges in the gizzard. In the specimen dissected by me the crop and gizzard were laden with the fragments of a small crab, the pieces being more comminuted in the gizzard.

The liver is a bulky gland, extending on each side of the crop as low down as the gizzard; it is divided into four lobes, connected posteriorly by a fifth transverse portion: the lobes are subdivided into numerous lobules of an angular form. The secretion of the bile is derived, as in other mollusks, from arterial blood; it is conveyed from the liver by two main trunks, which unite into one duct, about two lines from the laminated sac. The bile, having entered the sac, is diverted by a peculiar development and disposition of one of the laminæ from flowing towards the gizzard. The follicular structure of this and the other folds of membrane indicate their glandular character; and the entire laminated pouch may be considered as a more developed form of pancreas than the simple cæcum which represents that gland in some of the Gastropods. No other foreign secretion enters the alimentary canal, as there is not any ink-gland in the Pearly Nautilus.

The heart and large vessels, with their follicular appendages, are contained in a large cavity, subdivided into several compartments, which I have termed pericardium; it is separated from the branchial cavity by a strong membranous partition, in which the following orifices are observable. In the middle the termination of the rectum, to the left of this the orifice of the oviduct, and on each side at the roots of the anterior branchiæ there is a small mamillary eminence with a transverse slit, which conducts from the branchial cavity to one of the compartments of the pericardium containing two clusters of venous glands. There are also two similar, but smaller, slits contiguous to one another, near the root of the posterior branchia on each side, which lead to, and may admit sea-water into, the compartments containing the posterior clusters of the venous follicles.

The venous branches, from the labial and digital tentacles, and adjacent parts of the head and mouth, terminate, with those from the funnel, in the sinus, partly excavated in the body of the cartilaginous skeleton, and in part continued round the œsophagus. From this sinus, the great vena cava (*fig.* 217, *a*) is continued, running in the interspace of the shell-muscles on the ventral aspect of the abdominal cavity, and terminating within the pericardium by a slight dilatation (*c*), which receives by two veins (*d*) the blood from the different viscera. The vena cava is separated by a layer of decussating muscular fibres from the abdominal cavity, which closely adheres to the parietes of the vein. There are several small intervals left between the muscular fibres and corresponding round apertures (*b*) in the membrane of the vein and peritoneum. This communication with the diffused sinuses occupying the general abdominal cavity, is similar to that already noticed in the Aplysia*: M. Valenciennes detected the same structure in the specimen of the Nautilus dissected by him.†

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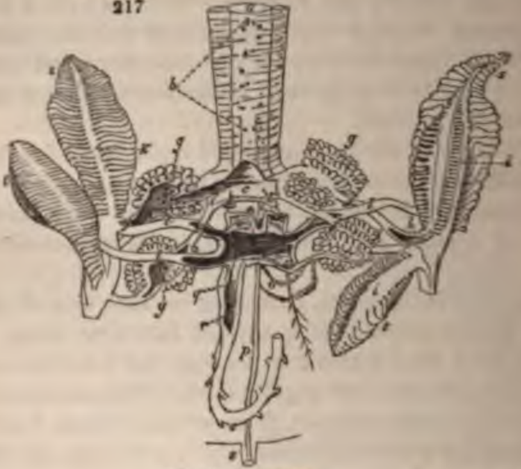

Nautilus Pompilius.

The branchial circulation may be considered to commence, when the blood again begins to move from trunks to branches, four of which trunks are continued from the terminal venous sinus to convey the carbonised blood to the four gills, of which there is a larger and a smaller one on each side. Each pair of gills is connected by a common peduncle to the inner surface of the mantle; the larger branchia consists of a central stem supporting forty-eight vascular plicated lamellæ on each side: the smaller branchia has thirty-six similar lamellæ on each side.

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* P. 559.

† Loc. cit. p. 287.

The four vessels (*f, f*) continued from the venous sinus have attached to them, in their course to the gills, clusters of glandular follicles (*g, g*) of a simple pyriform figure: each vessel has three clusters of such glands contained in the membranous receptacles above mentioned. The walls of these receptacles exhibit in some parts a fibrous texture, apparently for the purpose of compressing the follicles, and discharging the contents of the membranous receptacles into the branchial cavity, by the apertures above mentioned at the base of the gills. Doubtless, therefore, the glands are emunctories, and eliminate from the venous blood an excretion, most probably urine. Their homologues exist in the higher Cephalopod, in which they are considered to act as kidneys by Mayer; and it is more probable that the organs of so important an excretion should be present in all the class, than that they should be represented by the ink-gland and bag, which are peculiar to one order.

The veins (*f, f*) extend beyond the follicles each to the root of its respective gill, where it receives a small vein. At this part there is a valve (*h*) which opposes the retrogression of the blood; the vessel, which may now be termed branchial artery, penetrates the root of the gill (*i*), and dilates into a wider canal, which is continued through the soft white substance forming the branchial stem. A double series of branches are sent off from the lateral lamellæ, which ramify and subdivide to form the capillary plexus, from which the returning vessels terminate in the branchial vein. These veins (*l, l*) quit the roots of the gills, and return to terminate at the four corners of a subquadrate transversely elongated ventricle (*m*). From this ventricle two arteries arise, one superior and small (*n*), the other inferior (*r*), and strengthened by a muscular bulb (*q*) to the extent of nearly half an inch. An elongated pyriform sac (*o*) is attached by a contracted origin near the root of the large aorta, and dilates to a width of two lines; then, again contracting, becomes connected by its other extremity, to the venous sinus: it contained a firm coagulated substance.* The anterior aorta supplies the nidamental gland, and adjoining part of the mantle, and the rectum; then bends back to form the small artery (*p*), continued along the membranous siphon (*s*). The large aorta supplies the gizzard and ovary, winds round the bottom of the abdominal sac, sends off large branches to the liver, and regains the dorsal aspect of the crop, along which it passes to the œsophagus, distributing branches on either side to the great shell-muscles. It bifurcates near the beginning of the œsophagus, and terminates by furnishing branches to the mouth, the surrounding parts of the head and funnel.

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* CCCLXXXVII. p. 35. pl. 5. 18.

In the male Nautilus, at the part of the branchial cavity where the vulva opens in the female, there is a short conic penis, somewhat bent at the basis towards the ventral side, having an obtuse and perforated apex; a very narrow canal extends from this aperture to the base, and there expands into a pouch, of a firm parchment-like texture. This pouch contained a conglobate tube of a brown colour, of little more than a line in diameter: the walls of the tube consisted of an external transparent membrane, and an internal thicker tunic of circular fibres. In the interior of the tube was a narrow band disposed in close spiral convolutions. Between the spiral band and tube were several free oblong or navicular microscopic corpuscles. For so much knowledge of the male organs of the Nautilus — all that science hitherto possesses — we are indebted to Van der Hoeven.[*]

The female organs of the Nautilus consist of an ovary, an oviduct, and, as in the Pectinibranchiate Gastropods, of an accessory glandular nidamental apparatus. The ovary (*fig.* 214, *u*) is situated at the bottom of the sac on the right side of the gizzard in a peritoneal cavity peculiar to itself. It is an oblong compressed body, one inch and a half in length, and an inch in breadth; convex towards the lateral aspect, and on the opposite side having two surfaces sloping away from a middle longitudinal elevation. At the anterior and dorsal angle there is an orifice about three lines in diameter, with a puckered margin, which conducts into the interior of the ovary. It is filled with numerous oval ovisacs of different sizes, which are attached by one extremity to the ovarian capsule, but are free and perforated at the opposite end; are smooth exteriorly, but rugose and apparently granular on the inner surface, owing to numerous minute wavy plicæ adhering thereto. The largest of the ovisacs were four or five lines in length; they were principally attached along the line of the exterior ridge, at which part the nutrient vessels penetrated the ovary.

The oviduct (*fig.* 214, *v*) is a flattened tube of about an inch in length, and from four to five lines in breadth; it extends forward by the side of the intestine, and terminates at the base of the funnel close to the anus. It becomes enlarged towards the extremity, and is deeply furrowed in the transverse direction both within and without; the parietes are also here thick and pulpy, and apparently glandular. It is probable, however, that the ova derive an additional exterior covering and connecting substance from the secretion of a large glandular apparatus, which is situate immediately below the terminal orifice of the oviduct. This apparatus is attached to the mantle, and gives rise to the two rounded convexities observable on the ventral aspect of the body behind the funnel. It is a transversely oblong mass, composed of numerous close-set pectinated membranous laminæ, which are about a quarter of an inch in depth, and are disposed in three groups; those of the larger group extend transversely across the mesial line of the body, and are unprotected by a membrane; but the two smaller divisions are symmetrically disposed, and have the unattached edges of the laminæ covered by a thin membrane, which is reflected over them from the anterior margin of the glandular body. These divisions form the sides and anterior part of the gland; and as the secreted matter must pass backwards to escape from beneath the margin of the protecting membrane, this membrane may serve both to conduct the secretion nearer the orifice of the oviduct, and also to prevent its being drawn within the respiratory currents of water, and so washed away as soon as formed.

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[*] CCCXC.

In contrasting the organisation of the Nautilus with that of the inferior Mollusca treated of in the two preceding Lectures, we find the main advance to have been made in the organs of animal life.

A true internal skeleton is established in the Nautilus, and thus the lowest Cephalopod offers an approximation to the Vertebrate type, which not even the highest of the Articulate series had attained. Perfect symmetry now reigns throughout the animal and vital organs. The muscular system forms a larger proportion of the body, with various arrangements and complications unknown in the lower Encephalous mollusks. The respiratory tube, though still completed by the overlapping, not by the coalescence, of its side-walls, has received an enormous development as contrasted with the siphonated Trachelipods; and, by its powerful muscles and their firm cartilaginous basis of attachment, it is evidently endowed with a new function, in relation to propelling the Cephalopod with its testaceous dwelling through the sea.

The nervous centres concentrated in the head have received a marked increase of bulk, which, nevertheless, is still manifested more strongly in the inferior masses, and especially the anterior subœsophageal ring than in the superior or cerebral part. Here, however, we find for the first time in the Molluscous series, especial ganglions subordinated to the greatly enlarged organs of vision.

The organs of reptation, which had progressively advanced (as Lamarck's denomination of the higher Gastropods indicates) towards the head, are exclusively attached to that part in the Nautilus, and project from before the eyes and mouth. The mouth, besides its jaws and spiny tongue, is now served by organs of prehension; and it is most interesting to observe that these cephalic prehensile tentacula, at their first appearance, manifest the vegetative character in their multiplied repetition and comparative simplicity, compared with their homologues in the superior Cephalopods.

Some of the Gastropods have a pair of jaws working upon each other, but in the horizontal plane, as in insects: in the Nautilus they are opposed to each other vertically, as in the Vertebrate series, and they present a form which is repeated amongst fishes by the Scari, amongst reptiles in the Chelonia, and almost universally in the class of Birds. The resemblance to the latter class which the Nautilus offers in the modifications of the alimentary canal is also remarkable.

In the very few conchiferous Gastropods that are able to swim, the shell is of diminutive size, of a simple form and structure, and of an extremely light and delicate texture. The strong and muscular occupant of the Pearly Nautilus-shell would not have been able, notwithstanding its higher organisation, to have risen and swam on the surface of the ocean unless it had been relieved from the impediment of its large and dense abode by the introduction of some special modification in the testaceous structure.

This is effected by the adoption, in the Nautilus, on a more definite plan and larger scale, of the second mode of dealing with the part of the shell successively vacated during the rapid growth of the animal, which has been defined in the general account of the structure and formation of univalve shells given in the foregoing Lecture.* The abdominal part of the mantle of the Nautilus is attached to the inner surface of the shell by the intervention of a horny or epithelial cincture, the expanded lateral portions of which serve as the medium of insertion of the adherent muscles of the shell: the cavity of the shell posterior to this attachment is thus hermetically closed. A third point of attachment is to the bottom of the shell by the posterior extremity of the mantle, which probably presents a conical form in the embryo Nautilus. The line of attachment of both the muscles and the cincture progressively advances with the growth of the animal. A certain portion of the fundus of the shell thus becomes vacated, and the Nautilus commences the formation of a new plate for the support of the part of the body which has been withdrawn from the vacated shell. The formation of the plate proceeds from the circumference to the centre, and there meeting the conical process of the mantle, which retains its primitive attachment, the calcification is continued backwards for a short distance around that process, which now forms the commencement of the membranous siphon, and acquires the partial protection of the calcareous tube. An air-tight chamber is thus formed, traversed by the siphon, which perforates its anterior wall or septum; by a repetition of the same processes, a second chamber is formed, included within two perforated septa; and similar, but wider partitions continue to be added, concurrently with the formation of the new layers which extend and expand the mouth of the shell, until the animal acquires its full growth, which is indicated by the body having receded for a less distance from the penultimate septum before the formation of the last septum is begun.

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* P. 545.

The periodical formation of these septa in the progress of growth is analogous to that of the projecting external plates in the Wendletrap, and of the rows of spines in the Murex; but these external processes consist of the opake calcareous layer of the shell, whilst the internal processes in the Nautilus consist of the nacreous layer like the septa in the Turritella. Thus the embryo Nautilus at first inhabits a simple shell like that of most univalve Mollusca, and manifests, according to the usual law, the general type at the early stage of its existence; although it soon begins, and apparently before having quitted the ovum, to take on the special form.

In acquiring the camerated structure of the shell the Nautilus gains the power of rising from the bottom and the requisite condition for swimming; by the exhalation of some light gas into the deserted chambers it attaches to its otherwise too heavy body a contrivance for ascending in its atmosphere, as we ascend in ours by the aid of a balloon. But the Nautilus, superior to the human aeronaut, combines with the power of elevating and suspending itself in the aqueous medium, that of opposing its currents and propelling itself at will in any direction. It possesses the latter essential adjunct to the utility of the balloon as a locomotive organ, by virtue of the muscular funnel, through which it ejects into the surrounding water, doubtless with considerable force, the respiratory currents.

It appears that the proportion of the air-chambers to the dwelling chamber of the Nautilus and its contents, is such, as to render it of nearly the same specific gravity as the surrounding water. The siphon, which traverses the air-chambers, communicates with the pericardium, and is most probably filled with fluid from that aquiferous cavity.

Dr. Buckland* conjectures that the Nautilus may possess the power

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* CCCXCII. p. 328.

of ejecting such fluid into the siphon, and thereby of compressing the gas of the chambers and increasing the specific gravity of the shell. Such, indeed, were the siphon dilatable, would be the natural effect of the contraction of the animal within its shell. The consequent pressure of the dense anterior muscular segment upon the soft and yielding visceral cavity, resisted at the same time by the unyielding posterior plate at every point, save that from which the siphon was continued, would propel into that tube as much fluid as it might be capable of receiving. These consequences would follow the instinctive retraction of the animal when alarmed; and if they should take place while it was floating on the surface, it would immediately begin to descend. If, desiring to rise again from the bottom, the Nautilus should protrude its body from the mouth of the shell, extend the folds of its mantle, and spread abroad its tentacula, it would withdraw the pressure from the abdomen, and, by the act of advancing, create a tendency to a vacuum in the posterior part of the shell. The fluid in the siphon would then, if that tube were contractile, return into the pericardial cavity, the gas in the chambers would expand, and the specific gravity of the animal be sufficiently diminished to cause the commencement of its ascent, which would doubtless be accelerated by the reaction of the respiratory currents upon the water below.

Neither the contents nor the vital properties of the siphon are however yet known: an artery and vein are assigned for its life and nutrition, and to extend a low degree of the same influence to the surrounding shell: but the structure of the membranous siphon, in the specimens from which I have had the opportunity of examining it in a recent state, presents, beyond the first chamber, an inextensible and almost friable texture, apparently unsusceptible of dilatation and contraction: it is also coated beyond the extremity of the short testaceous siphon with a thin calcareous deposit. A graver objection to the hydrostatic action of the siphon is founded upon its structure in certain extinct species of Nautilus, as the *N.*[1] *Sipho*, in which it is provided through its whole extent with an inflexible outer calcareous tube, rendering it physically impossible that the gas of the chambers could be affected by any difference in the quantity of fluid contained in the siphon. In the *Nautilus striatus*, also, the calcareous siphon is a continous tube, slightly dilated in each chamber.

From these facts I incline to the conclusion, that the sole function of the air-chambers is that of the balloon, and that the power which the animal enjoys of altering at will its specific gravity, must be analogous to that possessed by the fresh-water testaceous Gastropods, and that it depends chiefly upon changes in the extent of the surface which the soft parts expose to the water, according as they may be expanded to the utmost and spread abroad beyond the aperture of the shell, or be contracted into a dense mass within its cavity. The Nautilus would likewise possess the additional advantage of producing a slight vacuum in the posterior parts of the chamber of occupation which is shut out by the horny cincture, and muscles of adhesion from the rest of that cavity.

Whatever additional advantage the existing Nautilus might derive, by the continuation of a vascular organised membranous siphon through the air-chambers*, in relation to the maintenance of vital harmony between the soft and testaceous parts, such likewise must have been enjoyed by the numerous extinct species of the tetrabranchiate Cephalopods which, like the Nautilus, were lodged in chambered and siphoniferous shells.

If the Nautilus extended itself in a straight line during its growth, instead of revolving round an imaginary axis, a straight conical shell would be produced, with the chambered part divided by simple septa concave next the outlet. Such are the more obvious characters of the fossil shells called *Orthoceratites*. The siphon is usually central, but sometimes marginal; it is testaceous throughout, and sometimes moniliform or dilated at each chamber: this structure, Dr. Buckland remarks, would admit of the distension of a membraneous siphon.† Mr. Stokes‡ has discovered in a species of Orthoceratite (*Actinoceras*) from Lake Huron, a second slender calcareous tube included within the moniliform siphon, which shows no corresponding partial dilatations, but is connected to the external siphon by successive series of radiating plates; the inner siphon was probably produced by a calcification of the membranous siphon, and of processes continued from it at regular intervals. The complex siphons of these *Orthoceræ* are of great relative capacity. In *Ormoceras* the siphuncular beads are constricted in the middle. In *Gomphoceras* the shell is fusiform or globular, tapering towards the aperture of the last chamber, which is much contracted, so as to suggest that the soft parts could not have been wholly retractible into that chamber. The chevron-shaped coloured bands preserved on *Orthoceras anguliferum* show that the shell, like that of *Nautilus*, was external. The *Orthoceratites* are abundantly and widely diffused through the palæozoic rocks: specimens of the *Orthoceras giganteum*, of the length of six feet, have been discovered in the carboniferous limestone in Dumfriesshire: they indicate a high temperature of the then existing climate of that northern latitude.

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* LXXXIV. p. 331. (1843). According to Vrolik (CCCXCIII.), the gas with which the chambers are filled consists chiefly of nitrogen, without a trace of carbonic acid.

† CCCXCII. p. 364.

‡ CCCXCV. p. 705.

I have already alluded to the slightly undulating contour of the margins of the septa in the Nautilus, which makes the surface next the aperture of the shell convex at one part and concave at another. In an extensive genus of extinct chambered shells called "Ammonites," no example of which has been discovered in strata more recent than the chalk, but which were exemplified under a rich diversity of forms before their final disappearance, the sinuosity of the margins of the septa is much greater, and most of the surface next the outlet is convex: the siphon perforates the septa at their centre in extremely few species, and in the rest is situated at that margin which is next the outer or ventral curve of the shell.[*] Certain chambered shells thus characterised are straight, like the Orthoceratites, but generally compressed, with their numerous septa joining the outer shell by foliated dentations: they are termed *Baculites*. In the true *Ammonites* the shell is discoid and coiled upon itself as in the Nautilus; but it is strengthened by arched ribs and dome-shaped elevations on the convex surface, and by the tortuous windings of the foliated margin of the transverse partitions. Separate casts of the interior of the chambers are not unfrequently obtained, which have become detached by the solution of the calcareous walls and septa of the shell, or are held together by the interlocking of the dove-tailed lobes of the margins of the chambers. The last chamber of the Ammonite was of large size, as in the Nautilus, and doubtless contained all the soft parts of the animal save the small proportion which was prolonged into the siphon. The aperture of the inhabited chamber was closed by an operculum. Certain species, described by Mr. Pratt[†], from the Oxford clay, were characterised by the production of a long and narrow process from each side of the mouth of the shell, indicating a corresponding modification in the lobes of the mantle, analogous to that which produces the auricular appendages of the mouth of the shell in certain Argonauts. The same gentleman has likewise recently shown me a small Ammonite, in which the mouth of the shell is arched over transversely by a convex plate of calcareous matter continued from the lateral margins of the outlet, and dividing this into two apertures, one corresponding with that above the hood of the Nautilus, which gives passage to the dorsal fold of the mantle; the other with that below the hood, whence issue the tentacles, mouth, and funnel: such a modification, we may presume, could not take place before the termination of the growth of the individual. This structure reminds one of *Gomphoceras;* to which illustration may now be added the more remarkable instance of the *Rhizochilus,* a siphonated univalve, in which both the outer and inner lip of the shell-aperture is extended, so as to cement the shell to the axis of a coral (*Antipathes ericoides*), or to another shell, and at length to reduce the aperture to the slender tube of the anterior siphon of the mantle,—the sole medium of entry and exit of the respiratory currents, and of the nutritive and excretory particles.

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[*] The dissection of the Nautilus proved that what had been called the ventral part of the ammonite was the *dorsal*.

[†] Annals of Nat. Hist., November, 1841.

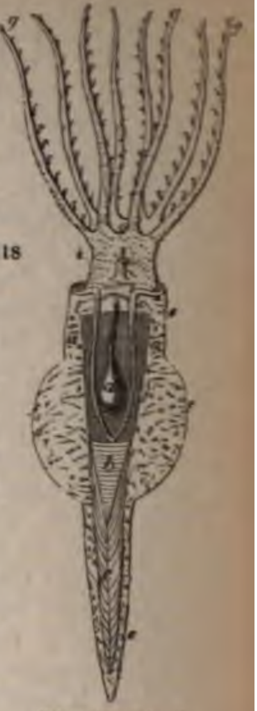
The *Turrilite* is essentially an Ammonite disposed in spiral coils. The *Hamite* and *Scaphite* are other modifications of the outward form of similarly constructed chambered shells: in the former the small extremity of the shell is curved, the rest being straight; in the latter both ends are curved towards each other like those of a canoe.

With none of these species has there ever been found a trace of the ink-bag; a part, indeed, of so delicate a texture that some surprise may be naturally felt that any evidence of its existence could be expected to be met with in a fossil state.

I shall, however, conclude this Lecture by bringing before you examples in which not only the ink-bag, but the muscular mantle, the fins, the eyes, and the tentacles and their horny hooks, of extinct Cephalopods have been preserved from the remote periods of the oolitic deposits to the present time. Independently of these and many other examples of the durability of the inky secretion of the gland which is peculiar to the naked Cephalopods, the absence of the organ in the shell-clad Nautilus, too well protected to need such means of temporary concealment, would lead to the inference that the ink-bag must have been absent in the other low-organised Cephalopods covered by chambered siphoniferous shells.

A more complicated fossil shell than any of the preceding, but allied to them by the camerated and siphoniferous structure of one of its constituent parts, once occasioned much perplexity amongst palæontologists; the evidence of its nature has however for some years been in the main sufficient to determine its affinities, about which there now appears to be no difference of opinion. The shell to which I allude is that called the "Belemnite," which is associated with the more obvious congeners of the Nautilus through a considerable range of the secondary rocks. It makes its first appearance, with *Teudopsis* and *Celæno,* in the Lias, as the precursors of the Calamaries and Cuttles.

The chambered part of the shell of this extinct Cephalopod has the form of a straight cone (*fig.* 218, *b*), the septa being numerous, with a slight and equable concavity directed towards the outlet or base of the cone. The intervening chambers are so shallow that



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Belemnite restored.

the septa have been compared to a pile of watch-glasses. They are traversed by a marginal siphuncle. The septa are chiefly composed of nacreous substance, with a thin layer of opake and friable calcareous matter on both surfaces, and the entire cone is enveloped in a sheath of opake calcareous matter lined with nacreous substance, and having on the outer surface, or there degenerating into, a pellicle or thin layer of a horny substance. This essential characteristic of the Belemnitic shell is called the "phragmocone." Its horny or albuminous tissue is continued forwards beyond its base, and forms the parietes of a cavity (*a*) containing some of the viscera of the animal. In some specimens, two blade-shaped processes of albumino-nacreous matter are prolonged forwards from the dorsal side of the phragmocone. This chambered part, with its sheath, is lodged in a conical cavity or alveolus* excavated in the base of a conical or fusiform, sometimes compressed, usually long and spathose body (*c*), resembling the head of a dart or javelin, whence the name "Belemnite," applied to this genus of extinct Cephalopods. This sheath or "guard" of the chambered cone is most commonly found detached from the rest of the shell, with its thin aveolar portion fractured, especially if fusiform, as in the younger Belemnites, when it is pointed at both ends. In this state it has been mistaken for the spine of an Echinoderm.

In the typical Belemnites with a spathose guard, this consists of successive layers, of which the exterior ones run parallel with the outer surface, and progressively increase in length as they approach it, thus forming the conical cavity for the lodgment of the chambered cone. The innermost or first-formed layers of the guard are not parallel with the outer ones, but recede from them at their upper extremity, where they form a point, and sometimes a dilated nucleus, in contact with the apex of the chambered cone. The interspace thus left between the early and the later strata of the guard is occupied by the coarse calcareous matter continued from the sheath of the chambered cone, and a filamentary process of apparently the same matter is continued down the centre of the guard to its apex.

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* The term alveolus has been given improperly to the contents of the socket, viz., to the "phragmocone."

The structure of the spathose layers of the guard is fibrous; the fibres being directed at right angles to the plane of the strata: viewed in thin sections by transmitted light it bears a close resemblance to that of the teeth of Pycnodont fishes; but certain proportions of the transverse fibres are apt so to intercept the light as to cause the appearance of elongated triangular dark specks, with their apices directed on one surface of the section to the periphery, and on the other surface to the centre of the guard.* The microscopic structure, which resembles that of the *Pinna*, proves this aggregation of subtransparent calcareous matter to be the effect of original formation, and not, as Walsh, Parkinson, and Lamarck supposed, of infiltration of mineral substance into an originally light and porous texture. A section of a Belemnite, in which the chambers of the cone have been filled with crystalline matter infiltrated from the water of the stratum in which the dead shell was imbedded, affords a favourable opportunity of contrasting the crystalline condition of the infiltrated matter with the organised texture of the solid guard.

The exterior surface of this guard always exhibits, when entire, traces of vascular impressions: it is sometimes granular, and presents other modifications, which prove that it was covered by an organised membrane in the living Cephalopod. I have occasionally seen the remains of a more immediate investment by a thin friable layer of calcareous matter analogous to that of the outer layer of the sheath of the chambered cone, with which layer it becomes continuous. The exterior of the spathose guard is generally impressed with a longitudinal groove extending from the apex upwards, sometimes along the ventral (*Gastrocœli*), sometimes along the dorsal side (*Notocœli*). In some of these the exterior of the guard is impressed with two opposite longitudinal channels in addition to the dorsal groove: the ungrooved Belemnites form the tribe called *Acœli*.

The septa of the chambered cone are perforated by a marginal siphon, situated in most Belemnites on the side which is nearest the dorsal line, or groove; but in certain species of Belemnites, characterised by the flattened form of the spathose guard, the siphon is on the opposite side. These Belemnites, which at first sight look like distorted or accidentally compressed specimens, are peculiar to certain members of the greensand formation, called the "older Neocomian."

Specimens of Belemnites have been discovered in which the spathose guard has been fractured during the lifetime of the animal;

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* CCCXCVI. p. 67. pl. vii. fig. 2.

but the broken portions have been held together by the investing organised integuments, and have been reunited by the deposition of new layers of the fibrous structure peculiar to the guard.*

The existence of a camerated and siphoniferous structure on this complex and remarkable shell, induced most zoologists to class it with the Ammonites and other more simple chambered shells. Mr. Miller having detected evidence of the internal position of the Belemnite in the exterior characters of the guard, first ventured upon a conjectural restoration of the entire animal†; and as only the dibranchiate type of Cephalopods was then known, he placed it in the body of a Calamary (*Loligo*), assigning to the terminal fins the office of clasping the guard and retaining it in its proper position.

The first evidence that bore directly upon the position of the Belemnite in the Cephalopodic class was detected by Drs. Buckland and Agassiz in specimens of Belemnite from Lyme Regis, in which the fossil ink-bag and duct was preserved in the basal chamber of the phragmocone. We must connect with this fortunate discovery the important fact, that remains of an ink-bag have never been met with in connection with any of the more simple or typical forms of chambered shells: we know that the ink-bag does not exist in the recent Nautilus; and it will be shown in the following Lecture that it is present in all the existing Cephalopods which possess more or less rudimental internal shells. I may here anticipate a few remarks on the relations of co-existence of the ink-bag with the organisation of the naked Cephalopods. These highly organised species enjoy active powers of locomotion, which would be incompatible with the incumbrance of a large external protecting shell; but, to compensate for the want of this defence, nature has provided them with the power of secreting an inky fluid, which, when alarmed, they eject into the surrounding water, and are concealed by the obscurity which they thus occasion. The branchial character of the naked Order of Cephalopods is an essential condition of their muscular powers. The presence of an ink-bladder, therefore, in the extinct Belemnites, would have implied the internal position of the shell, even if other proof had been wanting; and, by the laws of correlation, it implies likewise the presence of the muscular forces for rapid swimming, and the concomitant conditions of the respiratory, the vascular, and the nervous systems. Connecting, therefore, all these considerations with the detection of the ink-bag in the shell of the Belemnite, I could not hesitate in referring the Belemnites, and likewise the Spirula, on account of the ascertained internal position of its shell, to the Dibranchiate order; and I, therefore, separated these chambered and siphoniferous shells from the Nautilus and the Ammonites in the Classification of the *Cephalopoda* proposed in 1836.*

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* Duval-Jouve, Mémoire sur les Bélemnites. 4to. 1841. pl. x.

† Geological Transactions, N.S. vol. ii. p. 45. pl. ix. 1823.

Leopold Von Buch, who believed that he could trace in certain slabs containing Belemnites the impressions of the Cephalopods to which they belonged, concluded "that the body of the animal enveloped the greater part of the shell, and exceeded its length by eight or ten times."† Other considerations, taken from the shell itself, prove, as has already been shown, that it was wholly internal.

M. Duval, the latest and most accurate author on fossil Belemnites, reproduces the figure which M. D'Orbigny has published, and which is essentially the same as that given by Dr. Buckland in his Bridgewater Treatise; and, like it, differs from Mr. Miller's restoration, only in the position of the ink-bag and in the extended state of the terminal fins. With respect to these parts, M. Duval, from his discovery of the united fractures of the spathose guard, objects, with much acumen, that, if the fins of the Belemnite had been placed at the side of the guard, they must have been rendered useless by its fracture, and the creature, thus deprived of its power of swimming, would soon have fallen a prey to its numerous enemies, and would not have survived to exemplify the reparative powers of those ancient Cephalopods. It seemed vain to hope that the soundness of the principles on which the classification of the Belemnites with the dibranchiate Cephalopods had been definitely proposed, should ever be vindicated by an example of parts apparently so perishable as the mantle, the fleshy arms and fins of these Mollusca. I have, however, been enabled to examine and describe a fossil specimen, in which not only the ink-bag, but the muscular mantle, the head, and its crown of arms, are all preserved in connection with the most essential characteristic of the Belemnitic shell, viz., the phragmocone.‡ It appears to have been the peculiar property of the matrix, in which this and many similar valuable and instructive specimens were entombed, to favour the conversion of the muscular tissue into adipocire, and its subsequent preservation to the present time. Yet this matrix is a member of the Oxford-clay formation, belonging to the middle oolite system; older, therefore, than the Portland stone, the Wealden and the Cretaceous group. The Cephalopod, in which we may now study the microscopic character of the muscular fibre§, must therefore have existed at a period antecedent to the gradual deposition of these enormous masses of the secondary strata, which themselves preceded the formation of the entire tertiary series, and the overspreading unstratified masses called diluvial. The attempt to conceive or calculate the period of time which must have elapsed since the Belemnites were thus embalmed, baffles and awes the imagination.

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* CCCXCVII.

† Oken's Isis. Bd. xxi. p. 438.

‡ CCCXCVI. pl. v.

§ *Ib.* pl. vi. figs. 3 and 4.

A second less complete, but highly instructive, specimen of the same kind of Belemnite*, exhibited the funnel, a great proportion of the muscular parts of the mantle, and the remains of two lateral fins, the ink-bladder and duct, and a considerable portion of the chambered cone. The two fins (*fig.* 218, *f, f*) present the form of flattened transversely striated fibrous masses with their free border entire and rounded. They are situated on each side of the visceral cavity, and demonstrate the accuracy of M. Duval's objection to their position in the previous conjectural restorations. A large tract of the grey fibrous substance, running parallel with and on one side of the remains of the head, indicates the position of the infundibulum, and is terminated by a concave truncation. At the middle of the visceral mass at the interval of the two lateral fins, there lies a compressed body of a horny texture and somewhat bilobed form, on which may be clearly distinguished striæ passing outwards in opposite directions from a middle line, and diverging from each other in their course, which resembles that of the fibres of the digastric muscle in the gizzards of the Cephalopods: this apparent remnant of the stomach lies anterior to the ink-bladder. There is a strong negative evidence that the Belemnite possessed horny mandibles like the other naked Cephalopods, since no calcareous ones, called Rhyncholites, have been discovered associated with these remains. The cephalic arms, which are preserved in a third specimen with the contour of the large sessile eyes, belong to the normal series, and were eight in number: they were provided, not with simple acetabula, but with a double alternate series of slender elongated horny hooks, as in the genus of existing Calamaries, called *Onychoteuthis*. Each arm seems to have been provided with from twelve to twenty pairs of these hooks. They were doubtless developments of the horny hoop which encircles the central process of the acetabulum, as in the modern *Onychoteuthides;* but in the position of the pallial fins, the Belemnite resembled the *Sepiola*. The traces of the superadded pair of tentacula are somewhat doubtful.

The modern decapodous Cephalopod, which most nearly resembles the Belemnite in the structure of its internal shell, is the *Sepia*, or common cuttle-fish: the lateral fins of this species extend from the apex to near the base of the mantle. The nucleus, or terminal spine of the cuttlebone corresponds with the spathose guard of the Belemnite: the convex posterior broad layer of friable calcareous and horny matter is homologous with the enveloping cone; but its margins, instead of being approximated and soldered together, are free and lateral in position: the successive plates, embedded in its concavity, answer to the camerated cone of the Belemnite; but, instead of being perforated by one or many siphons, they are connected with each other by a series of minute undulating lamellæ.

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* CCCXCVI. pl. iii. For these apparently guardless species, first submitted to me by Mr. C. Pearce, I suggested the subgeneric name of *Belemnoteuthis*, which he adopted. But the importance of the subsequently discovered specimens, with the soft parts, for the elucidation of the nature of the *Belemnitidæ*, is in no way affected by subgeneric nomenclature, so long as naturalists concur in regarding the "phragmocone" as the essential part of the Belemnitic shell.

Thus at length has been obtained the proof of the dibranchiate nature of the Belemnite, and we learn from the same ocular evidence that it combined characters at present divided between three distinct genera of the order; namely, first the calcareous internal chambered shell, to which the *Sepia* offers the nearest approach; secondly, the formidable hooks of the arms, which characterise the modern genus *Onychoteuthis;* and, thirdly, the limited attachment of the lateral fins to a position a little in advance of the middle of the body, as in the *Sepiola.*

The Belemnite, having the advantage of its dense but well-balanced internal shell, must have exercised its power of swimming backwards and forwards, which it possessed in common with the modern decapod Dibranchiates, with greater vigour and precision. Its position was probably more commonly vertical than in its recent congeners. It would rise swiftly and stealthily to infix its claws in the belly of a supernatant fish, and then dart down and drag its prey to the bottom and devour it. We cannot doubt at least but that, like the hooked Calamaries of the present seas, the ancient Belemnites were the most formidable and predacious of their class.

LECTURE XXIV.

CEPHALOPODA.

THE deductions which were founded on the modifications of the chambered siphoniferous shell and other enduring remains of the very remarkable extinct genus which occupied our attention at the close of the last lecture, obliged me frequently to refer to the type of structure which characterises the *Dibranchiate* order of Cephalopods, and which places these Mollusks not only at the head of that division of the Animal Kingdom, but, in respect of its closer proximity to the Vertebrate type, unquestionably at the head of the whole Invertebrate series.

The body of the Dibranchiate Cephalopod is divided, as in the Nautilus, into two parts; a head (*fig.* 220, A.), containing the organs of sense, mastication, and deglutition, and supporting the prehensile and principal organs of locomotion (C), and a trunk or abdomen (B), consisting of a muscular sac or mantle, with a transverse anterior aperture, and containing the respiratory, generative, and digestive viscera. With the exception of the females of one genus (*Argonauta*, *fig.* 220.), the body is naked, includes a more or less rudimental shell, and supports, in most of the species, a pair of fins. Compared with the Nautilus, the cephalic appendages are much reduced in number, the external ones, continued from the oral sheath, not exceeding eight (*fig.* 219, *c, c*), to which, in most of the genera, is added a pair of internal and much longer tentacula (*d, d*). The arms are much increased in size and of a more complicated structure, supporting on their internal surface numerous suckers, and sometimes connected together by a powerful muscular web. The eyes are much larger and more complex, are no longer pedunculated, but lodged in orbits. The mouth is armed with two piercing and trenchant jaws, resembling in shape and in their vertical movements those of the Nautilus, but wholly composed of horn. The gills are two in number, each with a ventricle appropriated to the branchial circulation; the systemic circulation having a single muscular ventricle, as in the Nautilus. The infundibulum (*i*) is a complete muscular tube, shaped like an inverted funnel. The Dibranchiates possess a gland and membranous receptacle for secreting and expelling an inky fluid. The sexual organs are in distinct individuals, as in the Tetrabranchiate order. All the species of both orders of Cephalopods

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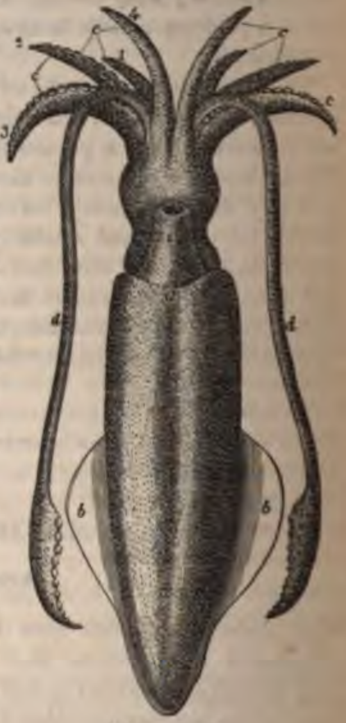

Loligo vulgaris.

are aquatic and marine, and they are mostly nocturnal and gregarious in their habits.

The Dibranchiate order may be subdivided into two tribes; the one provided with the eight ordinary arms and the two longer tentacles, hence called *Decapoda* (*fig.* 219.); the other tribe without the tentacles, and called *Octopoda* (*fig.* 220).

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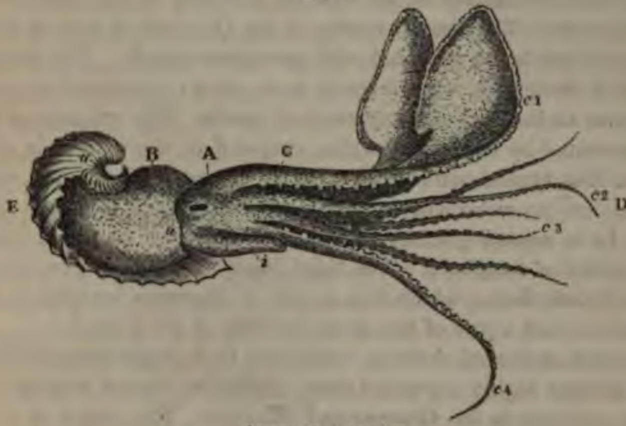

Argonauta Argo, fæm.

The various forms of the extinct *Belemnitidæ* (*fig.* 218.) constituted one family in the Decapod tribe. The little *Spirula*, characterised by a less complex, but internal, chambered shell (*fig.* 221.), is the type of a second family. The cuttle-fish, characterised by its internal calcareous shell, which feebly represents that of the Belemnite, exemplifies a third family of Decapods called *Sepiadæ*. The common calamary (*Loligo*), in which the internal shell is reduced to a horny quill-shaped plate, represents the fourth and most extensive family of the present tribe, which I have called *Teuthidæ;* and in which one genus (*Onychoteuthis*) had the caruncle of more or fewer of its acetabula produced into horny claws.* In all the Decapods the mantle supports a pair of fins (*fig.* 219, *b*, *b*), and the funnel is generally provided with a valve.

In the tribe *Octopoda* fins are rarely developed from the mantle; but the eight ordinary arms are longer, thicker, and are united together by a broader web, which forms a powerful organ for swimming in a retrograde direction. One family in this tribe (*Testacea*) is represented by the genus *Argonauta*, in which, in the female sex †, the first or dorsal pair of arms (*fig.* 220, *c*, 1) are dilated at the extremity into a broad thin membrane, like the mantle in the testaceous mollusks; by means of these membranes, the animal, in fact, forms for itself an extremely light, slightly flexible, and elastic, but calcareous, symmetrical shell, which is simple, and not divided into chambers; the vacated portion communicating with the rest, and being used by the inhabitant as the receptacle for the eggs: it has no muscular attachment to the body.[*] The siphon is without a valve, but is articulated at its base on each side to the inner surface of the mantle. The second family of the Octopods is termed *Nuda*, the species not being provided with an external shell. The first pair of arms is elongated, and contracts to a point: the funnel or siphon is without an internal valve or external joints. The rudimental shell is represented by two short styles, encysted in the substance of the mantle. The typical genus of this family is termed *Octopus*, in which the arms are provided with a double alternate series of sessile acetabula. In a second genus *Eledone*, the arms are provided with a single series of acetabula. The third family is the *Pinnata*, typified by the *Sciadephorus*, which has a pair of filaments between each of the suckers, and a pair of fins from the sides of the body.[†]

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* CCCXCVII.

† CCCXCVIII. p. 39.

The shell or dermal skeleton, which has been progressively reduced in the present highly organised class, attains its lowest or most rudimental condition in the *Octopus* and *Eledone*. The genus in which the shell most nearly resembles that of the tetrabranchiate Cephalopods, belongs to the *Spirula*. A few mutilated specimens had demonstrated it to be an internal shell, and the more perfect examples of the animal, dissected by M. de Blainville[‡] and myself[§], proved it to have the characteristic organisation of the Dibranchiate order, and to possess, as Péron had indicated, the eight short arms and the two long tentacula of the Decapodous tribe. The shell of the *Spirula* (*fig.* 221.) is perfectly symmetrical, convoluted in a vertical plane with the whorls contiguous, but not touching. The shell commences by a small oval cell, followed by a series of chambers (*b*), which rapidly increase in size. The septa (*a*) are concave towards the outlet, and are perforated by a siphon at the internal or concave margin of the shell. A small funnel-shaped tube (*c*) is continued backwards from each perforation; and its apex penetrates the mouth of the succeeding tube. The circumference of the siphonic aperture is impressed, as Mr. Stokes first observed, by a

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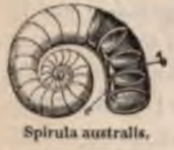

Spirula australis.

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[*] The honour of having experimentally determined the true relation of the Argonaut shell to its cephalopodic tenant, and the true functions of the expanded arms, is due to Madame Jeanette Power, CCLXXIII.

[†] CCCXCIX. & CCCC.

[‡] CCCCI. p. 396.

[§] CCCCII. pl. iv.

circle of minute pits. The shell seems to be exclusively composed of a fine white nacreous substance; it is imbedded in the posterior part of the mantle, with a small part of its surface exposed on both the upper and lower sides of the animal's body: the exposed parts of the shell are invested by a granular straw-coloured epidermis. The shelly siphon is traversed by a tubular membranous siphon.

The principal characters of the internal shell of the cuttle-fish have already been pointed out in the illustration of its analogies with that of the Belemnite. The preparations, Nos. 106, 107, 108. demonstrate the great proportion of animal membrane which enters into the composition of this slight friable laminated shell. The laminæ consist of a subopake minutely granular substance, and are connected together by thin wavy leaves of a transparent substance, the folds of which resemble little pillars, and are marked by fine transverse striæ, like those on the prisms of the shell of the Pinna.

In the rest of the Decapoda the rudimental shell consists exclusively of animal matter, of the consistency of horn, and presents either the form of a pen, as in the common Calamary, or that of a straight three-edged sword, as in the hooked squids.* This body was called "xiphos" by Aristotle, and "gladius" by Pliny. In *Sepioteuthis* it is as broad in proportion to its length as the cuttle-bone. In *Onychoteuthis*, *Loligo*, and *Loligopsis*, it is much narrower, but is as long as the mantle. In *Sepiola* and *Rossia* the gladius, commencing at the anterior margin of the mantle, ends before it has reached half-way down the back. In the *Octopus* and *Eledone*, the last traces of a shell exist in the form of two small amber-coloured styliform bodies, contained loosely in capsules in the substance of the mantle. All these bodies present a minutely laminated structure when transversely bisected. The shell of the Argonaut presents a minutely granular texture; "it exhibits no trace of cellular or prismatic tissue."†

The skin of the naked Cephalopods is generally thin and lubricous, and can be more easily detached from the subjacent muscles than in the inferior Mollusks. In some of the smaller Cephalopods it is semitransparent: it is densest in the Calamaries, in which the epidermal system is most developed, as is exemplified in the horny rings or hooks upon the acetabula. In the Octopods the epidermis is reflected over the interior of the acetabula without being condensed into horn. Upon the body the epiderm may generally be detached in the form of a thick white elastic semitransparent layer. The second, or pigmental layer of the skin, analogous to the rete mucosum, consists of numerous cells of a flattened oval or circular form, containing coloured particles suspended in a fluid. The colour is rarely the same in all the cells; the most constant kind generally corresponds more or less closely with the tint of the inky secretion. In the *Sepia* there is a second series of vesicles containing a deep yellow or browish pigment: in the *Loligo vulgaris* there are three kinds of coloured vesicles, yellow, rose-red, and brown: in the *Octopus vulgaris* there are four kinds of vesicles, red, yellow, blue, and black. In the skin of the Argonauta all the colours which have been observed in other Cephalopods are present, and contained in their appropriate cells. These cells possess the power of rapid alternate contractions and expansions, by which the pigment can be driven into the deeper parts of the corium or brought into contact with the semitransparent epiderm. If the skin of a living *Octopus* be touched, the colour will be accumulated, gradually or rapidly, like a cloud or a blush upon the irritated surface. If a portion of the skin be removed from the body and placed in sea-water under the microscope, the contractions of the vesicle may be watched for some time: their margins are well defined, and they pass, during their dilatations or contractions, over or under one another. The power which the Cephalopods possess of changing their colour and of harmonising it with that of the surface on which they rest, is at least as striking and extensive as in the Chameleon, in which, it seems, from the latest observations, to be produced by a similar property and arrangement of pigmental cells. The external surface of the branchial membranes in the Argonauta has many pigmental cells; the internal surface has very few; it is covered by numerous reticulated lines, which become prominent, and their interspaces deep, when the membranes contract.

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* In some extinct Cephalopods from oolitic strata the shell was externally calcareous, internally horny, e. g. *Coccoteuthis*. See CCLXXII.

† CCXXXI.

The internal organised skeleton of the dibranchiate Cephalopod is cartilaginous, as in the Nautilus, but consists of a greater number of pieces, and enters into a larger proportion of the organisation of the animal. The cranial cartilage is no longer limited in its position to the under side of the œsophagus, but completely surrounds that tube, which, together with the inferior salivary ducts and the cephalic branches of the aorta, traverses a narrow canal in its centre. The cartilage above forms the cavity containing the brain, while below it is excavated to lodge the organ of hearing, and at the sides expands into the broad and thick orbital cavities. There is also a thin and long cartilage which supports the eyeball, and reminds one of the ophthalmic peduncle of the Rays and Sharks. A process continued from the anterior part of the cranial cartilage expands into a broad transverse plate, and gives attachment to the muscles of the arms. In *Sepia* and *Loligo* there is a thin semilunar cartilaginous plate, situated on the dorsal part of the mantle, near the anterior end of the internal shell: in *Loligo*, there is a second long rhomboid dorsal cartilage. The infundibular cartilage, which is a process of the cranial one in the Nautilus, is a distinct piece in the *Dibranchiata*. It is of a large size, and of a flattened triangular figure in the cuttle-fish, in which it is situated above the base of the funnel. It consists of three distinct portions in the Calamary. On each side the base of the funnel there is a smooth oblong articular cavity, formed by a distinct piece of cartilage, which is articulated with a corresponding cartilaginous prominence from the inner surface of the side of the mantle. These cartilaginous joints of the funnel vary in shape in the different genera: they are wanting in the *Octopus*. The lateral fins of the *Decapoda* are each supported by a narrow flattened elongated cartilaginous plate, which forms the medium of attachment of the powerful muscles of those fins. These appear to be homologous with the parial fins of fishes; but as they are not fixed to a vertebral column, their position is variable; in the *Rossia*, for example, they are situated near the anterior part of the body; in the *Loligo*, they are placed at the posterior extremity; in the *Sepia* they extend, like the great pectoral fins of the Rays, along the whole side of the body. In the Octopods the mantle-fins and their cartilages are wanting, except in the anomalous genus *Sciadephorus* in which they are attached to the anterior part of the sides of the mantle.

The sole locomotive organs in the ordinary Octopods and the sole prehensile organs in all the Dibranchiates are the appendages developed from the head, termed "arms," "feet," "tentacles," and "proboscides." They have no true homology with the locomotive members of the Vertebrata, but are analogous to them, inasmuch as they relate to the locomotive and prehensile faculties of the animal.*

The eight arms of the *Octopus* commence by a hollow cone of muscular fibres attached by a truncated apex to the anterior part of the cephalic cartilage. The fibres are for the most part oblique, and interlace with one another in a close and compact manner, as the cone advances and expands to form the cavity containing the mandibulate mouth, at the anterior extremity of which they are continued forward, and separate into eight distinct portions which form the arms. The development of the eight external arms bears an inverse proportion to that of the body: they are longest in the short round-bodied *Octopi*, and shortest in the lengthened Calamaries and Cuttle-fishes, in which the two elongated retractile tentacles are superadded by way of compensation. These latter organs are not continued from the muscular cone which corresponds with the cephalic sheath in the Nautilus, but arise, like the internal labial processes in that Cephalopod, close together from the cephalic cartilage, internal to the origins of the ventral pair of arms. They proceed at first outwards to a large membranous cavity situated anterior to the eyes, and emerge between the third and fourth arms on either side.

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* Geoffroy St. Hilaire regarded the cuttle-fish as a vertebrate animal bent double, with the approximated arms and legs extending forwards: a similar comparison may be found in Aristotle.

In most Octopods the two dorsal arms are the longest: they are ten times the length of the body in *Oct. Aranea*. But besides their superior length, the dorsal arms present other peculiarities in this family of Cephalopods. In the males of *Tremoctopus* and *Argonauta*, one of them is enlarged and excavated to receive part of the male sexual apparatus*: in the female *Argonauta* they are provided, as before stated, with the expanded calcifying membranes (*fig.* 220, *c.* 1), which are usually spread over the exterior of the delicate shell (*a*), meeting and overlapping each other along its slender keel. The fabled office of these membranes, as sails to waft the argonaut along the surface of the ocean, and that of the attenuated arms as oars extending over the sides of the boat, have afforded subject for poetic imagery and constructive analogy in all ages: and the little hypothetical navigator of nature's ship has been the subject of the disquisition of the naturalist from Aristotle to Cuvier, and of the song of the poet from Callimachus to Byron.

In *Octopus velifer* both the first and second pairs of arms support broad and thin membranous appendages at their extremities. In the common Poulp, *Octopus vulgaris*, the eight arms are connected together for some distance beyond the head by membranes and muscles, which form a circular fin; this constitutes its sole locomotive organ when swimming, and, by its powerful contraction, aided, however, by the ejection of the currents from the funnel, the animal is propelled through the water by a quick retrograde motion. In *Oct. semipalmatus* the fin is extended along the basal interspaces of only the four dorsal arms. In *Sciadephorus* it extends between all the arms, and as far as their attenuated extremities. There are two layers of transverse fibres in this web, the external of which arises from a white line along the back part of the base of each arm, the internal from the sides of the same arms between the attachments of the suckers. They decussate one another as they pass from arm to arm in the middle of the webs, and are included between two thin layers of radiating or longitudinal fibres.†

The internal surface of the arms is that which is specially modified in the Dibranchiate as in the Tetrabranchiate Cephalopods for the prehensile and tactile faculties; but the structure is much more complicated in the higher order. On this surface each arm supports a single or double series or more numerous rows of acetabula or circular sucking cups: in the elongated pair of superadded tentacles of the Decapods the suckers are limited to the expanded extremities, where they are generally aggregated in more numerous and irregular rows. These tentacles serve to seize a prey which may be beyond the reach of the ordinary arms, and also act as anchors to moor the Cephalopod in some safe harbour during the agitations of a stormy sea.

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* CCCCIX. & CCCCX.

† Eschricht, CCCXCIX. p. 627.

Each muscular arm is perforated near the centre of its axis for the lodgement of its nerve and artery (*fig.* 222, *a*), which are surrounded by a layer of cellular tissue (*c*); from the dense outer sheath of this cellular canal the transverse fibres of the arm (*d*) radiate to the periphery, intercepting spaces containing the longitudinal fibres of the arm, the whole being surrounded by two thin and distinct strata of fibres, of which the external is longitudinal, and the internal transverse.

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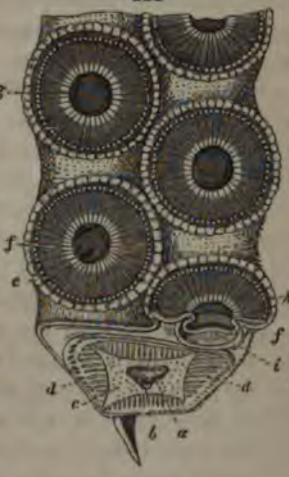

Octopus.

The mechanical structure of the acetabulum may be favourably studied in the *Octopus*, in which those organs are of large size, and sessile. The circumference of the disc of the sucker is raised by a tumid margin (*h*); a series of slender folds of membrane (*f*), covering corresponding fasciculi of muscular fibres, converge from the circumference towards the centre of the sucker, where a circular aperture (*g*) leads to a cavity which widens as it descends, and contains a soft caruncle (*i*), rising from the bottom of the cavity like a piston of a syringe. When the sucker is applied to any surface for the purpose of adhesion, the piston, which previously filled the cavity, is retracted, and a vacuum produced.

The complex irritable mechanism of all these suckers is under the most complete control of the predatory Cephalopod. My friend Mr. Broderip, F.R.S.*, informs me, that he has attempted, with a hand-net to catch an Octopus that was floating within sight, with its long and flexible arms entwined round a fish which it was tearing to pieces with its sharp hawk's bill; the Cephalopod allowed the net to approach within a short distance of it, before it relinquished its prey, when in an instant it relaxed its thousand suckers, exploded its inky ammunition, and rapidly retreated under cover of the cloud which it had occasioned, by quick and vigorous strokes of its circular web.

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* Author of valuable original Memoirs in the Transactions of the Zoological Society; of the admirable articles on zoology in the Penny Cyclopædia;

The Cephalopods which frequent the more open seas, and which have to contend with more agile and powerful fishes, have still more complicated organs of prehension. In the Calamary the base of the piston is enclosed in a horny hoop with a dentated margin. In the Onychoteuthis the margin is produced into a long, curved, sharp-pointed claw. These formidable weapons are sometimes clustered at the expanded terminations of the tentacles, and in a few species are arranged in a double alternate series along the whole internal surface of the eight ordinary arms, as they were in the extinct Belemnite.

The peripheral fold of membrane of the sucker can be expanded beyond the piston, so as to act on a hard surface like the unarmed sucker of the Octopus: but, so applied to the mucous surface of a fish, it might glide off: the better to hold on such slippery ground, the horny dentacles and hooks are superadded; the latter, in *Onychoteuthis*, are retractile, as in the cat's paw; and it is interesting to find this earliest appearance of the retractile claw illustrating numerically the law of vegetative repetition.

In connection with the uncinated acetabula at the extremities of the long tentacula of the Onychoteuthis, may be observed a cluster of small simple unarmed suckers at the base of the expanded end. When these parts in each tentacle are applied to one another, they become locked together, and the united strength of both the peduncles is thereby more effectually brought to bear upon any resisting object which may have been grappled by the terminal hooks. This is a very striking mechanical contrivance: human art has remotely imitated it in the fabrication of the obstetrical forceps, in which either blade can be used separately, or, by the interlocking of a temporary joint, be made to act in combination.*

In the diminished number, increased size, and progressive complication of the cephalic muscular appendages, and in their final modification for combining with one another to produce a determinate action, we trace the common order which regulates the development of other

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of "Zoological Recreations," and other delightful contributions to our common favourite science.

[*] CCCCIV. vol. i. p. 529.

parts of the animal organisation. In our past review of the Invertebrata, we have witnessed this order in the appearance of the more essential organs, as the nervous centres, the eyes, the stomach, the heart, the gills, the generative parts; we find it equally regulating the development of the peculiar prehensile instruments of the Cephalopodic class.

At first very numerous, comparatively small and feeble, essentially alike, the cephalic tentacles of the Nautilus strikingly illustrate the law of vegetative or irrelative repetition. Their primary import is, however, plainly indicated by the direct derivation of their central nerve from the anterior cephalic ganglion; and they present the same complex plan of arrangement of their muscular fibres which characterises the arms and tentacles of the dibranchiate Cephalopods. The prehensile surface of the tentacula of the Nautilus (*fig.* 214.) is made adhesive after the type of the simple laminated sucker of the Remora; the median longitudinal impression which partially divides the lamella may represent the complete interspace which separates into two series, in the arms of most of the Dibranchiates, the more complex suctorial appendages which are developed on their internal surface: but at all events, the reduction of these arms in number, their augmentation in size, and perfection as prehensile instruments by the superadded complications, are phenomena which ordinarily attend the march of development. The order of this progress would be anomalously reversed if the tentacles of the Nautilus represented, as M. Valenciennes supposes, the caruncles of the acetabula, and the hollow processes of the oral sheath the cavities of those appendages of the arms of the Dibranchiates. According to the French Malacologist, the anterior circumference of the head or oral sheath in the Nautilus represents four of the eight arms developed therefrom in the Dibranchiates, and the two dorsal arms consist each of two enormous acetabula, whose cavities are deepened into tubes, and whose caruncles are produced into tentacula as highly organised in regard to their nerves and muscles, as are the acetabuliferous arms themselves in the higher orders. The four other arms of the Octopus are represented, according to M. Valenciennes, by the four groups of tentacula which are included within the oral sheath in the Nautilus. Such is not, however, the place of origin of any of the eight arms in the Dibranchiata; nor is it conformable with the general law of development, that a prehensile organ consisting of two large and highly complicated acetabula in a low organised Cephalopod should support two hundred smaller and more simple suckers in the higher organised species.*

* CCCCIII.

The primitive fibres of the muscles of the Cephalopods are smooth: they are more parallel than in the lower mollusks, and are bound together, so as to form well-defined flat fasciculi.

The pallial sac is chiefly composed of a layer of circular fibres, interrupted behind in *Sepia*, where the shell is lodged. A pair of round longitudinal muscles pass from the ventral wall to the base of the funnel: a second pair extend from the dorsal wall to the cephalic cartilage and the back part of the base of the arms. Other smaller fasciculi arise from the sides of the cephalic cartilage, and are inserted into the funnel.

Fasciculi of muscular fibres are continued from the ventral pair of feet and the back part of the cranium to the muscular partition which divides longitudinally the branchial cavity: other fibres descend to join the muscular tunic enveloping the liver and œsophagus. In the cuttle-fishes and calamaries the branchial septum is not developed. The respiratory tube or funnel is a complete muscular cylinder, formed by an external longitudinal, and an internal transverse, layer of fibres, with which are blended the insertions of the accessory retractor muscles.

The homologues of the great muscles which attach the Nautilus to its shell may be traced in the different genera of Dibranchiates, diminishing in size as the internal shell becomes more and more rudimentary. They arise in conjunction with the fibres of the fleshy tunic of the liver from the posterior part of the cephalic cartilage; but, soon quitting these fibres, they extend downwards and outwards, being perforated in their course by the great lateral nerve, and are inserted into the epidermic capsule of the internal shell.

The thin shell of the female Argonauta, which is external in regard to the true mantle, but internal in relation to the branchial membranes which formed it, is retained in its position chiefly by these membranes; and when they are, as they are capable of being, retracted into the cavity of the shell, it adheres to the surface of the body by the adhesion of contact only and its own elasticity, not by its attachment to any muscular fibres: hence the animal commonly drops out of the shell when dead.

The principal muscular fibres of the pallial fins extend, transversely to the axis of the body, to the margins of the fins: they present the same direction in the fossilised fins of the animal of the Belemnite. The action of the powerful muscles in the terminal fins of the calamaries must be aided in its effect upon the body by the elasticity of the internal pen or gladius. By these means they are enabled not only to propel themselves forward in the sea, but they can strike the surface of the water with such force as to raise themselves above it, and dart like the flying fish for a short distance through the air. This is the highest act of locomotion, the nearest approach to flight, which any of the molluscous animals have presented.

We find associated with the varied and active powers of locomotion just described, visual organs of large size and singular complexity of structure; the whole surface of the body is highly sensitive; and there is a concomitant development of the nervous centres, which exhibit the highest conditions of this system in the Invertebrate series of animals.*

The brain is lodged in a cartilaginous cranium, together with a portion of the œsophagus, from which it is separated by the membrane analogous to the dura mater: the same strong membrane protects the brain where the cranium is open anteriorly. Between that part of the fibrous membrane which lines the cerebral cavity and the pia mater covering the brain, there is an intervening space filled with a gelatinous and oily arachnoid tissue. In the cuttle-fish, the super-œsophageal cerebral mass (*fig.* 223, *a*) consists principally of a cordiform body, superficially divided into two lateral lobes by a median longitudinal furrow. From the lower and lateral parts of this body proceed the short and broad optic nerves, which constitute the peduncles of the large reniform optic ganglions (*b*), and upon each peduncle there is placed a small spherical medullary tubercle: these tubercles exist also in the calamaries, but appear not to be present in the Octopods.

From the inferior and anterior parts of the super-œsophageal mass, a thick cord descends on each side of the œsophagus, unites with its fellow, and dilates below that tube to form the anterior sub-œsophageal

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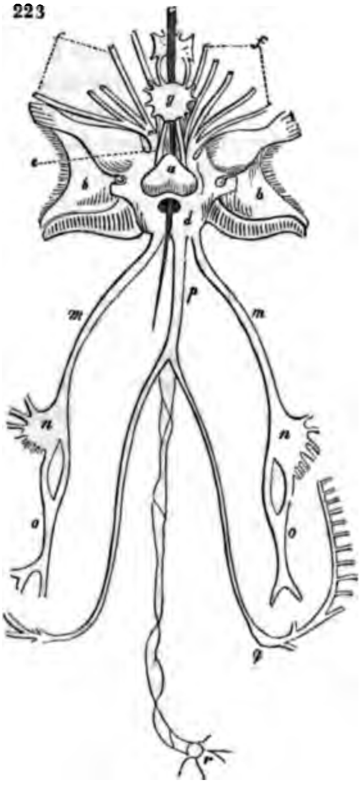

Nervous system, Sepia officinalis.

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* CCCXXI., CCCCIV., CLXXXV., Bd. ii. p. 317. t. 32., & CCLXXVIII.

ganglion, from which the nerves of the feet and tentacles arise. Two broader bands descend from the super-œsophageal mass behind the preceding, and form, by a like enlargement and union, the posterior œsophageal body, which blends laterally with the anterior one, and forms with it a large mass with a central perforation. Four short and slender chords, two of which (*e*) are continued from the anterior apices of the optic lobes, and two from the anterior sub-œsophageal lobes, converge forwards and unite to form a round flattened ganglion (*g*), which is closely applied to the back part of the fleshy mass of the mouth above the pharynx, from which are sent off the nerves to the retractors of the mouth. Two filaments from the pharyngeal ganglion descend to join a pair of ganglions below the pharynx, homologous with the labial ganglions of the Nautilus, and the buccal ganglions of Gastropods. The nerves of the arm (*f*, *f*) proceed from the anterior sub-œsophageal ganglion, and correspond in number to the organs which they supply, being eight in the *Octopoda*, and ten in the *Decapoda:* the corresponding nerves are much more numerous in the Nautilus. In the *Loligo* they have a double origin, the anterior sub-œsophageal mass being divided into an anterior and posterior portion, and each brachial nerve deriving a root from both centres, which may have distinct functions, one motory, the other sensory.* In the Octopus the brachial nerves pass along the inner surface of the base of the arms before they penetrate the axial canals. As soon as the acetabula begin to be developed, a series of closely approximated ganglions are formed upon the brachial nerves, of which some of the longitudinal fibres pass over the ganglions. Before the ganglionic enlargements commence, each brachial nerve in the Octopus gives off two large branches, which traverse the fleshy substance of the base of the arms to join the two corresponding branches of the contiguous nerves which are thus associated together for consent of action by a nervous circle.

The infundibular nerves arise behind the origin of the brachial ones. Posterior to these the small acoustic nerves are given off from the sub-œsophageal mass. The delicate motores oculi arise from the upper part of the lateral connecting bands of the infra- and supra-œsophageal masses, which may be compared with the crura cerebri, as the nerves in question obviously answer to the third pair in the Vertebrata. The nerves going to the cavities, supposed to be olfactory, arise close to the optic nerves. The nerves which correspond to those of the shell-muscles of the Nautilus, form a single large pair (*m*, *m*), which arise from the posterior and lateral angles of the sub-œsophageal mass, extend outwards and backwards, perforate the shell-muscles, and form the large stellate ganglions (*n*, *n*), from which the nerves of the mantle are principally derived. In the *Octopoda* this may be described as the termination of the nerve-trunk; but in the *Decapoda*, in which lateral fins are superadded to the body, the great nerve previously divides into two branches, of which the outer one expands into the ganglion, whilst the inner branch, having been joined by one of the rays of the ganglion (*o*, *o*), pierces the fleshy substance of the mantle, and ends in a diverging series of twigs appropriated to the muscles of the fin. In proportion as the trunk of the Cephalopod is attenuated and elongated, the pallial nerves become more parallel in their course, more dorsal in their position, and more similar to a rudimental spinal chord of which the two lateral columns have retained their primitive embryonic separation. The ganglions (*n*, *n*) are connected by a transverse commissural nerve in *Loligo*.*

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* CCLXXVIII. p. 2.

The two large visceral nerves (*p*) arise from the interspace of the origin of the pallial pair; after distributing filaments to the muscles of the neck they descend parallel and close to one another behind the vena cava, give off the small filaments which constitute the plexus upon that vein and around the œsophagus, then diverge from each other towards the root of each gill, where they divide into three principal branches: one of these dilates into an elongated ganglion (*q*) and penetrates the fleshy stem of the branchia; the second descends to the generative organs; the third passes to the middle or systemic heart. The œsophageal plexus unites into a ganglion (*r*), attached to the parietes of the gizzard in the interspace between the pyloric and cardiac orifices. Some filaments connect the ganglion with the œsophageal nerve sent off from the buccal ganglion (*s*).†

With respect to the parts of the brain in the Vertebrata, which are represented by the cephalic nervous masses in the Dibranchiate Cephalopods, we may regard the cordiform superior mass (*a*), which is principally in communication and coexists with the large and complex eyes, as the homologue of the optic lobes; it cannot be the cerebellum, as Cuvier supposed, for that body never gives origin to any nerve; the cerebellum is also less constant than the optic lobes of the Vertebrate brain, and is posterior to them in both position and order of development. The smaller super-œsophageal mass, anterior to the optic lobes in the Octopus and some other cephalopods, may represent an olfactory lobe, or the rudiment of a true cerebrum. I have already indicated the parts which seem to represent the crura of the cerebrum ; they unite with that large sub-œsophageal nervous mass, which, since it gives origin to the brachial nerves or the homologue of the fifth pair, to the acoustic and respiratory nerves, and to those two large moto-sensory columns which resemble in their structure, position, and distribution, the spinal chord of the *Vertebrata*, must be regarded as the representative of the medulla oblongata : it is obviously the part of the nervous centre which is most intimately connected with the vitality of the animal, and which is therefore here, as in the higher animals, the deepest seated and best protected part of the nervous system.

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* XXIV. & CCLXXVIII. p. 9., pl. 1. *i.*

† Ib. p. 10.

The disposition of this system determines the surfaces of the body of the Cephalopod which correspond with those of the fish. The nervous centre (*a*, *fig*. 223.), in which, from its comparative independence of, or indirect connection with, nerves, sensations are most probably raised into ideas, denotes the dorsal aspect, to which, as in the *Vertebrata*, the term "neural" would not be inapplicable, regard being had to the value of the brain-mass marking the aspect, and to the corresponding position of the chief nerve-trunks of the body. Thus, in the Argonaut (*fig*. 220.), B, E, A mark the dorsal aspect, *i* the ventral one, D the anterior part, and C the posterior part. The homology of the cerebrum (*a*, *fig*. 223.), with the reduced super-œsophageal mass (*a*, *fig*. 215.), determines unequivocally the true dorsal or neural aspect in that and all inferior forms of mollusk. But the inconstancy of the position of the heart and chief vascular developments for breathing, renders the terms "neural" and "hæmal," as now accepted for the Vertebrata, too arbitrary or contradictory for the Mollusca.

The integument is remarkable in several of the naked Cephalopods for its irregular surface, which seems designed to increase its natural sensibility : in some, it is provided with flattened crenate processes ; in others it is beset with branched papillæ ; in a third with simple obtuse papillæ ; in a fourth with pointed tubercles ; all which projections may serve to warn the animal of the nature of the surfaces with which it may come into contact. The margins of the acetabula and the attenuated flexile extremities of the arms which support them doubtless possess a delicate sense of touch. The fringed circular lip presents another example of the dermal covering modified to be the seat of this sensation.

The tongue is as highly developed for the exercise of the sense of taste in the Dibranchiate Cephalopods as in the Nautilus. In *Onychoteuthis* (*fig*. 225.), the fleshy part of the tongue is "produced into three caruncles (*e*, *f*, *g*), very soft in texture, and beset with numerous papillæ."*

Siebold and Kolliker† describe the olfactory organs of the Dibranchiates as situated in the neighbourhood of the eyes, and consisting each of a cavity with tumid borders, or of a cutaneous fossa which has an opening and, sometimes, at the bottom, a whitish papilla. The nerves of this organ arise from the optic ganglion. They are at first closely united with the optic nerves, enter the orbit with them, and extend along its posterior wall to the olfactory papillæ, to which they are distributed in a radiated manner.‡ The sense of smell has been attributed to the Cephalopods by all naturalists who have observed their habits from Aristotle to Cuvier. It appears that the ancient Greek fishermen were in the habit of attaching strong-scented herbs to their baits to deter the cuttle-fishes from coming to devour them.

The organ of hearing consists of two vestibular cavities, excavated in the thick and dense under part of the cartilaginous cranium which supports the sub-œsophageal ganglions.§ In *Sepia* and *Loligo* several obtuse elastic processes project from the inner surface of the cavity, which contains a delicate sacculus and otolite. A slender canal, lined by a ciliated epithelium, forms part of the vestibule in the embryos of *Sepia* and *Loligo*.‖ The acoustic nerve is spread over the sacculus, and is impressed by the movements of the otolites, which respond to the sonorous vibrations that may be strong enough to affect the body generally. The sinuosities in the intervals of the vestibular processes seem to be the first rudiments of those which in Vertebrata are extended in the form of canals and spiral chambers, within the substance of the dense nidus of the labyrinth. In the Octopus the vestibules are nearly spherical with a smooth internal surface; the otolite is hemispherical; in the Eledone it is shaped like the shell of a limpet, with the apex rounded and curved backward, and appears not be calcified : in other Cephalopods the otolites contain carbonate of lime.

The orbit in the cuttle-fish is formed posteriorly by a thick cartilaginous cup (*fig.* 224, *a a*), and is completed anteriorly by a dense white fibrous dermal membrane (*b*), which becomes transparent at the anterior part of the globe, and forms the cornea (*c*). The cornea and the fibrous tunic are lined by a thin serous membrane, which is reflected over the anterior part of the sclerotica (*d*), passes through its anterior aperture (to which the cornea does not adhere), like the membrane of the aqueous humour, and is finally continued into the groove of the crystalline lens (*p*).

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* CCCCIV. p. 532., fig. 218.

† XXIV. p. 381.

‡ CCCXCI.

§ CCCLXXIX. p. 380.

‖ CCCXCI. p. 105.

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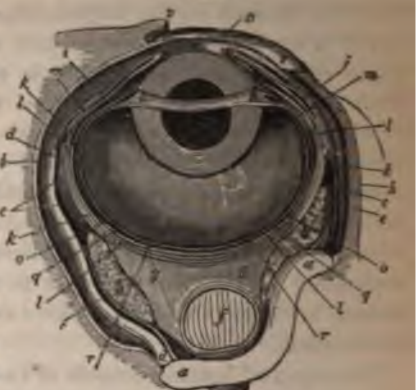

Sepia officinalis.

The space between the eyeball and its capsule, thus circumscribed, is filled with an aqueous humour, by which the cornea is separated from the eyeball, and kept tense. The outer tunic of the proper eyeball is a fibrous membrane (*d*) covered by the aponeurotic expansion of the muscles of the eye, and with an anterior aperture which is closed by the crystalline lens. Within the fibrous tunic there is a thin cartilaginous coat (*e*) perforated posteriorly by the numerous fibrils from the optic ganglion (*gg*). The layer of fibrous membrane (*m*) is continued from the anterior margin along with the outer fibrous layer (*i*) to form the pupillary aperture (*n*), which is encroached upon by a bilobed process analogous to the curtain, which depends from the iris of the ray. The cartilaginous sclerotic is lined by a thick expansion of the nervous fibres given off from the optic ganglion. These fibres are sent off from the outer surface of the ganglion, which presents a pulpy texture in its centre. They are grouped into flattened bundles, which decussate each other before perforating the cartilaginous sclerotica, and, after expanding into the retina (*o o*), extend towards the groove of the crystalline lens, and, being joined by a thin membrane from the anterior margin of the cartilaginous sclerotic, it forms a ciliary plicated zone (*p p*), which penetrates the groove of the crystalline lens.

The inner surface of the retina is covered by a layer of dark pigment (*q*), which is penetrated by the papillæ of the retina. The vitreous humour has a distinct and strong hyaloid coat. The crystalline lens is of large size, and consists of two distinct parts; the anterior or smaller moiety being the segment of a larger sphere, and the posterior that of a smaller sphere: they are separated by delicate transparent membranes continued from the ciliary body. The lens presents the same denticulated fibrous structure arranged in concentric laminæ, as in the higher animals.

The large optic ganglion (*f*) is imbedded in a white lobular substance (*h*), which defends it from the pressure of the muscles of the eye-ball. These consist of three straight muscles and one oblique, which take their origin from the orbital cartilages, and expand upon the sclerotic tunic of the eye-ball. The cornea of the cuttle-fish is perforated by a minute hole near the inner or anterior margin. In the Octopus the corresponding aperture is somewhat larger, and situate more in the axis of vision. In the Calamaries the corneal aperture is still larger, of a vertically oblong form, and the capsule of the crystalline lens, which projects through the sclerotic aperture, is immediately exposed to the sea water.

The Dibranchiate Cephalopods are, without exception, predatory and carnivorous animals. We have seen that they are endowed with formidable organs for seizing and overcoming the struggles of a living prey, and their strong sharp hooked jaws are well adapted for destroying and lacerating them when caught. The jaws (*fig.* 225, *a*, *b*; *fig.* 227, *k*, *l*) are sheathed upon a firm fleshy substance (*c*), the fibres of which are so attached to the base of the mandibles as to open them; their closure is effected by fasciculi of muscular fibres which surround them externally.

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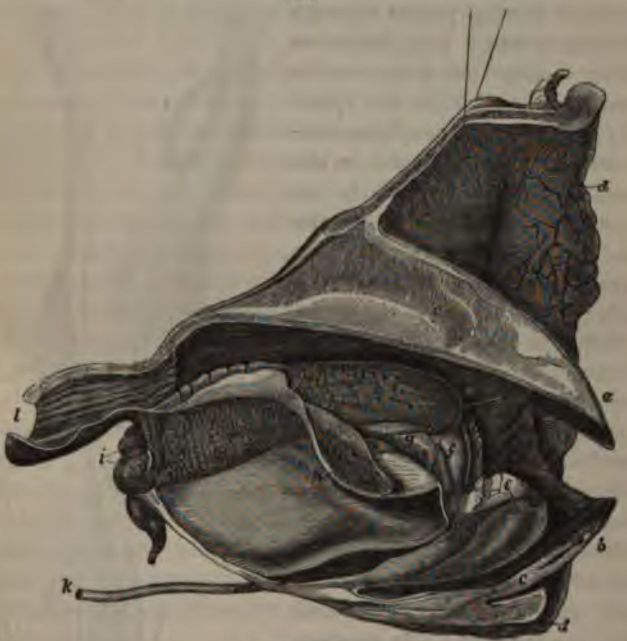

Onychoteuthis.

The tongue is partially covered with a horny plate (*f*), beset with recurved spines, which must assist in the further comminution an deglutition of the food. The fauces are also provided with spinig rous folds (*h*, *h*) of membrane. In some of the Calamaries, in whic the superior salivary glands (*i*) penetrate the folds, the ducts ope upon the inner surface, as in the Nautilus. In the Octopus the anterior or upper salivary glands are on the outside of the buccal mas In most of the Dibranchiates, including the *Spirula*, a second an larger pair of salivary glands is situated on each side of the œsophagus, at the commencement of the abdominal or hepatic cavity their ducts unite to terminate below the tongue in the concavity o the lower mandible.

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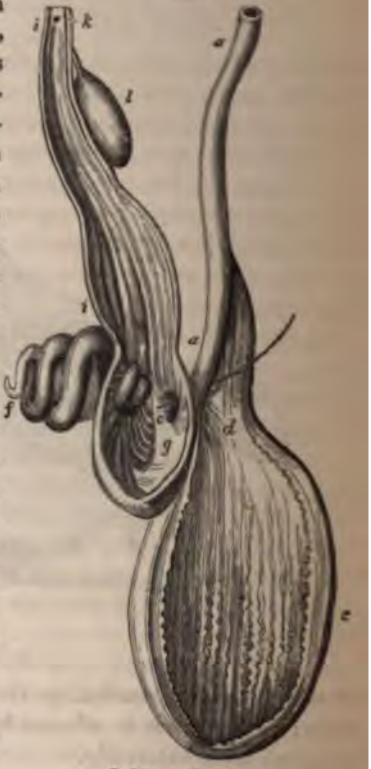

Loligo sagittata,

The peritoneal membrane is divided and disposed as in the Nautilus, in order to form special receptacles for the different viscera. The œsophagus, in all the Dibranchiates, is narrower than in the Nautilus; its inner surface is disposed in longitudinal plicæ: in both the Octopus and Argonaut it dilates, soon after having passed through the cranium, into a long ingluvies, forming a large cul-de-sac at its commencement; but in the Decapods (*fig.* 226, *a*) it continues narrow and of uniform breadth to the stomach. This cavity (*c*) is an elongated sac, presenting, in the disposition of its muscular fibres, in the proximity of the cardiac (*d*) and pyloric (*e*) orifices, and in the thickness of the epithelial lining, the usual characters of the gizzard. The intestine, at a short distance from the pylorus (*e*), communicates with a glandular and laminated sac (*g*), analogous to that in *Nautilus*, and presenting a similar globular form in *Rossia* and *Loligopsis;* it is elongated in *Loligo vulgaris*, and spirally convoluted in *Sepia* and *Loligo sagittata* (*f*). It receives the biliary secretion between two broad lamellæ, as in *Nautilus*. The intestine is very short in all the Dibranchiates. In *Octopus* it is bent upon itself (*fig.* 227. *r*), as in

Nautilus; but in *Sepia* and *Loligo* (*fig.* 226, *i*) it is continued forwards in a straight line, from the stomach to the vent. Its internal membrane is longitudinally folded, but is smooth at the short tract beyond the entry of the duct of the ink-bag (*k*); its termination is constricted either by the muscular fibres of the branchial septum, or by those which connect together the pillars of the funnel. In most Decapods provided with fins for swimming forwards, the anus can be closed by rhomboidal (*Sepia*) or triangular fleshy valves (*Sepioteuthis*): in *Loligopsis* these are modified into the form of antennal filaments. There is no ciliated epithelium in the intestinal canal of the Cephalopods.

The liver (*fig.* 227, *x*) is of large size in the Dibranchiates, but of more simple form than in *Nautilus*. It is usually of a reddish yellow colour. In *Sepia* it is divided into two lateral lobes, which are notched at the upper extremity; in *Onychoteuthis* it is a simple, elongated, compressed lobe with undivided extremities: in *Octopus* it forms a single oval mass, flattened anteriorly: in *Eledone* it is spherical, corresponding with the ventricose visceral sac. In the two latter genera the ink-bag (*d*) is enclosed within the capsule of the liver, and was mistaken for the gall-bladder by some of the early anatomists of these Mollusks; but in the Argonaut and the Decapods it manifests its distinct function by its separate position. The liver is surrounded by a smooth capsule, and is not subdivided externally into lobules, as in the Nautilus and lower Mollusca. The biliary ducts in the Octopods are simple canals which unite and terminate by a common orifice in the pancreatic sac. In the Decapods they receive the ducts of numerous clusters of cæcal appendages beyond the smooth part of the liver, which may perform a function analogous to the pancreas.*

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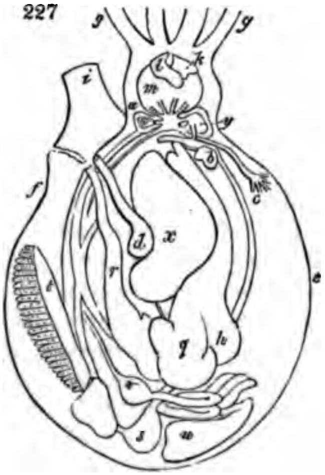

Octopus.

The ink-bag consists of tough white fibrous texture, the outer surface of which is coated by a thin silvery or nacreous layer; its inner surface presents a fine spongy glandular texture. It is usually of an oblong pyriform shape, as in *Octopus* (*fig.* 227, *d*), *Sepia*, and *Loligo* (*fig.* 226, *l*); but it presents at certain seasons a trilobate form in the Sepiola, in which Peters[*] has observed it to contract regularly. It is a very active organ, and its inky secretion can be reproduced with great activity. The tint of the secretion varies in different species, as is exemplified, in its inspissated state, by the Italian pigment called "sepia," and the Chinese one, called "indian ink." It is also very durable, as is shown by its frequent preservation in a fossil state in both the extinct Calamaries and the Belemnites. It is affirmed by some chemists to contain a peculiar animal principle, which Vizio has termed "melanine."

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* Prep. No. 775. X., vol. i. p. 229., & CCCLXXX. pl. 41, L.

Many of the Cephalopods possess the power of emitting a luminous secretion.[†] All of them are nocturnal and social animals, and are readily attracted by bright metallic substances.

Prior to the dissection of the Pearly Nautilus, the Cephalopods were regarded as having three distinct hearts; but two of these, which are appropriated to the branchial circulation, are peculiar to the higher order, and are perhaps the main-spring of their superior muscular energies.

In the Dibranchiates the venous blood returns from each arm along its lateral and posterior parts by two veins, which severally unite at the base of the arm with the opposite vein of the adjoining arm, the whole being ultimately conveyed to an irregular circular sinus, which surrounds the pharynx, and is continued between the head and the funnel into the great anterior cava (*fig.* 228, *a*). In *Octopus* this vessel is provided with two semilunar valves at its commencement; in *Sepia* with a single valve. At its entrance into the pericardium it usually receives two large visceral veins, returning the blood from some large irregular

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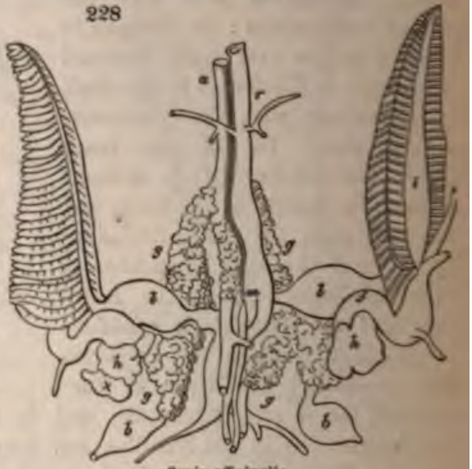

Sepia officinalis.

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[*] XXIV. p. 329.

[†] Linnæus quotes a passage from Bartholinus, illustrative of the luminous surface of a species of *Octopus* which shone so brightly, "ut totum palatium ardere videretur." This phosphorescence might be post-mortem, and the result of commencing decomposition.

abdominal sinuses, and it divides into two branches (*g*, *g*), continued downwards and outwards to the branchial hearts at the base of each lateral gill: previously to communicating with these it dilates into a sinus, which receives the venous blood from the sides of the mantle. The two divisions of the vena cava, and also the visceral veins (*b*, *b*), after having entered the pericardium, are furnished with clusters of glandular follicles, which open into these veins by conspicuous foramina. The follicles vary in form in different genera; in *Eledone* they are elongated and pyriform: in *Argonauta* and *Octopus* they are shorter, and arranged in distinct clusters: in *Loligo* they are represented by a spongy thickening of the tunics of the veins: in *Sepia* the secerning appendages are more elongated, but are very numerous, close-set, and of an irregular form, giving a floccular character both to the great divisions of the vena cava and to those parts of the visceral veins which are contained in the pericardial or great venous cavity. The special compartments, into which these glandular appendages to the veins are lodged, communicate with the respiratory cavity by two papillary orifices, situated near the base of the gills. Cuvier had suggested that these appendages might serve to eliminate some principle from the blood: and, as the kidneys derive their peculiar excretion from venous blood in the lower Vertebrata, Mayer's supposition* that the venous follicles of the Cephalopods were analogous organs, was not an improbable one: it has since been confirmed by the discovery in them of purpurate of ammonia.† They may serve in a secondary degree as temporary reservoirs of the venous blood when it is impeded in its course through the gills; and, as the venous follicles are endowed with a peristaltic motion, they may regulate the quantity of blood transmitted to the gills.

The accessory hearts (*fig.* 228, *h*, *h*) are situated one at the base of each gill. The regurgitation of the blood into the glandular veins is provided against by the interposition of the two semilunar valves at the entry of the ventricle, where it receives the blood from the great vein. In the Decapods and in the Argonaut, each branchial ventricle has a fleshy appendage (*x*) attached to its lowest surface. Cuvier correctly observes that the ventricle itself is more cellular than fleshy‡: but its direct connection with the branchial inferent vessel, and its valvular structure, incline me to regard it as more properly belonging to the circulatory than the aquiferous system.

A single branchial vein which dilates into a small sinus (*fig.* 228, *l*) returns the blood to a single median systemic heart, which is rounde in the Octopods, lozenge-shaped in the Calamaries, and fusiform, b bent upon itself, in the *Sepia* (*m*) *Sepioteuthis*, and *Sepiola*. I sends off two aortæ, as in the Nautilus, the larger or posterior on (*r*) being provided with a muscular bulb, and with two semicircula valves at its origin. The distribution of the large aorta very closel resembles that of the Nautilus. The vascular ring which encircle the œsophagus typifies the branchial arches in the Vertebrate animal but it supplies the head and all its complex radiating appendages Dilatations of the branchial arteries, like accessory hearts, have been observed * in the substance of the arms of the great Calamary (*Lolig sagittata*). Hugh Miller, in a vivisection of this species, saw "th yellow tubular heart propelling into transparent tubular arterie yellow blood," and he noticed lying detached from it "the two deeper-coloured hearts." † The small aorta supplies the stomach, intestine, branchiæ, and genital organs.

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* Analekten für Vergleichenden Anatomie, 4to. 1835.

† XXIV. p. 400.

‡ CCCXXI. p. 20. pl. ii. fig. 3, 12.

The branchiæ (*fig.* 227, *t. fig.* 228, *i*) are two in number, as the name of the order indicates. They are concealed, as in the Nautilus, by the mantle, *f*, which extends in front of the viscera to form the branchial chamber: the muscular tube called the funnel (*fig.* 227, *i*) projects from its outlet. The rectum opens into the branchial chamber at the base of the funnel, manifesting the same relation of the breathing organs to the termination of the alimentary canal, which characterises the Mollusca generally. Each gill consists, as in the Nautilus, of a number of triangular vascular laminæ, extending transversely from either side of the fleshy glandular stem, and decreasing in size to the extremity of the gill: each plate is composed of smaller transverse laminæ, which are themselves similarly subdivided, the entire gill presenting the tripinnate structure, which affords an extensive, though close-packed, surface for the minute subdivision of the blood-vessels. In *Loligopsis* each gill has twenty-four pairs of plates: in *Sepia*, thirty-six pairs; in *Loligo sagittata*, sixty pairs. The stem of the gill is not only attached by its base, but by a thin fibrous membrane through nearly its whole length to the mantle; the branchial artery extends along the attached border or stem, the branchial vein along the free border: the circulation through the artery is accelerated by the contraction of the surrounding fibres of the stem.

The mechanical part of the respiratory act is performed by the muscular actions of the mantle and funnel, the gills not being provided with vibratile cilia, as in many of the inferior Mollusks. The water is admitted into the branchial cavity at the anterior aperture of the mantle, outside the base of the funnel. Two large valvular folds of fibrous membrane, which are concave towards the respiratory cavity, prevent the currents from escaping by this entry: they are, therefore, propelled by the whole force of the contraction of the muscular mantle through the cavity of the funnel, the base of which is articulated, in most of the Cephalopods, by lateral joints, with the sides of the anterior aperture of the mantle.

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* CCCCVI.

† CCCXCIV. p. 447.

Although the apertures which I first pointed out in the Nautilus, near the base of the gills, are situated on prominences, which seem intended rather to let excretions out than fluids in, they are regarded by Siebold as being, together with some analogous apertures in the Dibranchiates, parts of an "aquiferous system." This system is described by that usually accurate and sound-judging anatomist* as "occupying the entire trunk of the Cephalopods, and terminating by two orifices, between which lies the duct of the ink-bag, and which are often situated on a small tubular eminence of the peritoneum. Each of these orifices leads to a spacious thin-walled cavity, near the pericardium. It contains the two venæ cavæ, with their appendages, and communicates by orifices and canals with other aquiferous cavities surrounding the various viscera, as *e. g.* the stomach and cæcum, and the two so-called branchial hearts. There is another system of aquiferous canals under the skin of the head and neck. It consists of several large reservoirs, which extend somewhat deeply between the organs of this portion of the body. These reservoirs communicate externally by orifices situated upon different points of the head." The peritoneal and pericardial orifices in some cartilaginous fishes, and the peritoneal orifices in the crocodile, are the last homologous traces of the aquiferous system of the marine invertebrates: but the valvular structure of the orifices is opposed to the idea of their performing a similar function, viz., admitting water into the peritoneal and pericardial cavities. And further research is needed to determine what actually goes in or out of the openings between the branchial and peritoneal cavities in the Cephalopods.

The Cephalopods are diœcious: the males are fewer; and generally smaller, than the females; and some species have more definite outward sexual characters.

In a male *Nautilus pompilius*, V. der Hoeven† found, beneath and external to the internal labial processes, a fold from which a dismemberment of the right external labial process, consisting of the confluent sheaths of four tentacles, projected. On the left side, in the place of the external labial process, there was a conoid process 2½ inches long, also formed of four tentacular sheaths, one of which was shorter and terminated freely, the other three remained confluent to the end of the process: it occupied much of the space included by the external circle of tentacular sheaths.

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* XXIV. p. 398.

† CCCXC.

The male Argonaut has an analogous modification of the tentacular system, indicative of its sex. Not any of the cephalic arms are sail-shaped, but one of them is longer and much thicker than the rest, and its double series of suckers are longer and more numerous.* In the female Argonaut (*fig.* 220.), two of the arms develope the broad and thin membranes, which form, repair, and usually overlap the delicate nidamental shell†, which is peculiar to this sex.‡ In the Calamary (*Loligo vulgaris*), the gladius of the male is one-fourth shorter, but is broader than that of the female. The sepium of the Cuttle (*Sepia*) shows a similar, but not so much sexual, difference in its proportions. In the Dibranchiates the male organs consist of a testis, a vas deferens, a vesicula seminalis, a prostate, the sac of the spermatophora, and the penis.

The testis is situated in a particular compartment of the peritoneum at the bottom of the visceral cavity; that membrane being reflected over it, from one point, to form its serous capsule: it is simple, roundish or oblong, and consists of a fibro-membranous pouch (*fig.* 229, *a a*), to one part of the inner surface of which are attached a number of slender branched tubuli (*b*), diverging, dichotomising, and terminating in blind extremities: the tubuli swell at the breeding season, burst, and discharge an opaque white fluid, crowded with spermatozoa, into the cavity of the sac, whence it escapes by a contracted orifice (*c*) into the slender and convoluted vas deferens (*d*), where the fluid is moulded, by the addition of a mucous secretion, into a cylindrical coherent mass. In this state it is transmitted to a wider glandular canal (*e*), having fibrous parietes and a cellular cavity in *Octopus*, and being encroached upon, in *Sepia*, by a plicated production of the lining membrane: this division of the efferent part of the male apparatus answers to the glandular part of the oviduct in the female: here the spermatozoa are enclosed in filamentary sheaths of albuminous matter, of a definite form, according to the species of Cephalopod. The anterior extremity of this contractile vesicula communicates, in *Octopus*, with a wide, bent, cæcal tube (prostate, *f*), with thick glandular parietes, and having the form of a simple pouch in *Sepia*, from which a short and wide duct leads to a longer and larger pyriform pouch, "Bursa Needhamii," or spermatophorous sac

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* CCCCIX. and CCCCX.

† CCCCVIII.

‡ CCCXCVIII.

(*g*), with thinner walls, containing the spermatophores, or moving filaments of Needham*, and from which pouch the short muscular penis (*k*) is continued. The prostate, in *Sepiola*, communicates by a long and slender duct with the vesicula seminalis. The moving filaments (*h*) in the terminal pouch are capsules of spermatozoa and sperm-fluid, with a singular associated mechanism. They form one of the most remarkable peculiarities of the Cephalopoda, and have been regarded as parasitic worms, under the names of *Echinorhynchus*, *Scolex dibothrius*, *Needhamia expulsatoria*, &c.; but were rightly recognised as sperm-holders by Swammerdam.†

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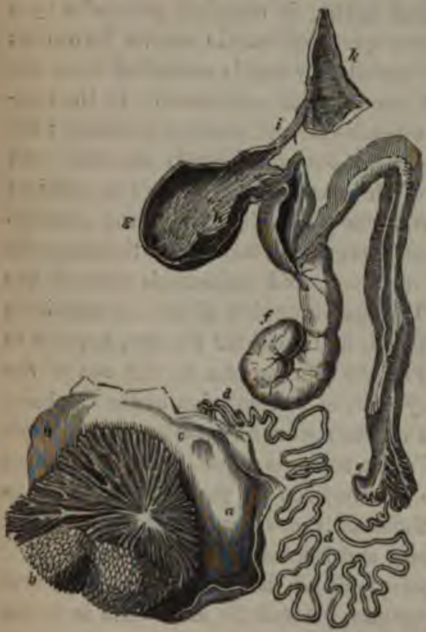

Male organs, Octopus.

In *Octopus* (*fig.* 229, *h*) they are from six to eight lines in length, slightly enlarged at one extremity. Their outer tunic or capsule is elastic and transparent: this contains an elongated sac, occupying the larger extremity of the sheath, and filled with the minute clavate spermatozoa. This sperm-sac communicates by a short narrow canal or isthmus, with a second narrower, elongated sheath, inclosing a highly-elastic piston, from which a spiral filament is continued to the small extremity of the outer sheath. In the Cuttle-fish, the isthmus connecting the sperm-sac with the ejaculatory sac is longer, and the coils of the spiral membrane are closer and more numerous. The spermatophores of the Calamary are remarkable for the superior size and length of the internal sac containing the spermatozoa. Under every modification, the analogy of the apparatus which forms the receptacle of the essential particles of the fertilising fluid, with the nidamental sacs containing the ova in the opposite sex, is very obvious. The spermatophores in the bursa are regularly arranged in superimposed longitudinal layers: their anterior ends directed forwards, their opposite ends often bound together by interlaced filaments. The movements of the spermatophores, when liberated from the sac, are truly remarkable: the smaller extremity of the outer capsule, to which the spiral spring is attached, protrudes by a kind of inversion, and the inner spermatic sac is drawn forwards; the action is repeated until the ejaculatory sac is extended from the sheath, when there is a slight cessation of movement. It then recommences; the sperm-sac is compressed and protruded farther; the isthmus gives way, and the spermatozoa are violently expelled, both outwards and into the cavity of the external sheath. The efficient cause of the movements appears to be a combination of the contractility of the external sheath and sperm receptacle, with the elasticity of the spiral membrane, and the very rapid endosmosis through the highly hygroscopic capsule. The final intention of the superaddition of protecting sheaths for the semen, like those for the ova, appears to relate to the safe conveyance of the spermatozoa to the ova of the female, there being apparently no true intromission in the Cephalopods; the peculiar mechanism of the sperm-receptacles insures their rupture and the dispersion of their contents after their brief transit through the sea-water. The spermatozoa in the Octopods have a small button-shaped head: those of the Decapods have a longer cylindrical head, and a very long and slender tail.

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* CCLXXVIII.

† CCXXXIII.

The spermatozoa in the receptacle of the modified cephalic arm (*Hectocotylus*) of the male Argonaut present the same form as in the *Eledone*.

The cumulative experience of numerous observers, since 1839, had led to the conviction that the Argonauta, with the expanded arms and shell, was the female form of the species.[*]

The discovery of the male has been attended with such difficulties as we have seen to beset the like problem in some of the lower invertebrata.

Della Chiajé first (1828)[†] figured and described an organism which he found attached to the female Argonaut, and which he believed to be a parasite, describing it under the name of *Trichoce-*

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[*] CCCXCVIII. "He had dissected every specimen of Argonaut in the present collection, in which the absence of ova in the shell left the sex doubtful, and they all proved to be females: this fact rendered it allowable to conjecture that the calcifying brachial membranes, and consequently the shell, might be sexual characters and peculiar to the female." "Should it be hereafter proved that the male Argonaut possessed neither a shell nor the organs for secreting it, this fact would not render the hypothesis of the parasitism of the female, which does possess the calcifying membranes, at all the less tenable." p. 39.

[†] CCCLXXIII. vol. ii. p. 225. taf. 16. fig. 4.

phalus acetabularis, on account of the number of suckers with which it was beset. In the following year, Cuvier, having received a similar organism which Laurillard had detected in a Cephalopod called *Octopus granulosus*, also believed it to be a parasitic worm, for which he proposed the name of *Hectocotylus Octopodis* *, assigning the name of *Hectocotylus Argonautæ* to the previously-observed species.

In 1842 Kölliker †, having detected the same organism, apparently parasitic on the female Argonaut, carefully scrutinised its structure, found that of the skin, with its complex pigment cells, and that of the acetabula, identical with the same parts in the Argonaut: he detected, moreover, in a dilated hollow part of the organism, a quantity of spermatozoa, having the characteristic form of those of the Octopod *Eledone*, and came to the bold conclusion that it was the long-sought-for male of the Argonaut, arrested in its development, and subsisting parasitically on the female, like the diminutive males of the Rotifera, Epizoa, and Cirripedia. It may serve as a wholesome warning against entering upon a scrutiny of parts whilst prepossessed by a foregone conclusion, to remember that the acute and usually accurate observer describes and figures the digestive, circulating and respiratory organs of the same supposed independent individual male animal.

Verany ‡ first had the good fortune to discover the Hectocotylus, or presumed parasitic male Argonaut, forming one of the arms, singularly modified and developed, of a little Octopod, which he figured under the name of *Octopus Carenæ*. Müller §, Rüppell, and others were not slow in demonstrating that this, or a similarly modified Octopod, was really the male of the Argonauta.

As in the spiders, which some Cephalopods so singularly resemble in outward form, certain species of the Octopod family have the male apparatus extended into one of the cephalic arms. In the Araneidæ the spermatic reservoir of the palp is quite isolated from the testis of the abdomen: in the *Octopus granulosus* and *Argonauta argo* the spermatic duct is continued from the testis, which occupies the usual position in the abdomen, into the base of the sexual arm, and opens into a dilated reservoir at the termination of that singularly modified member. It is somewhat longer than the longest of the ordinary or unmodified arms, and is much thicker. The acetabula are larger and more numerous, but retain the arrangement in a double row. The structure of these suckers, and of the skin, resembles that of the homologous parts in the female Cephalopod, as Kölliker most acutely made out: the other modifications of the arm relate exclusively to the impregnating function assigned to it.

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* CCLXXVI. vol. xviii. pl. 11.

† CCLXXVII.

‡ CCLXXV.

§ CCLXXIV.

One presumes that, in the coitus, the arms of the two sexes being mutually interlaced, as described by Aristotle, the expanded receptacular end of the modified arm, with the spermatozoa, is introduced into the funnel of the female: but with whatever part of her surface the masculine arm comes into contact, it adheres thereto forcibly by means of the double close-set row of large suckers. In the violent act of termination of the embrace, whether through alarm or other cause, the modified arm is snapped off and left adhering to the female by the suckers, where it long retains the power of motion. Such is the conclusion of the long-mooted questions of the Argonaut, its shell, the use of the brachial membranes or "sails," and the true sexual distinctions of the male and female.

The female organs consist in the Dibranchiate Cephalopods, as in the Nautilus, of an ovarium, oviduct, and, usually, nidamental glands, but with several modifications in the efferent part of the apparatus. The ovary is always single, of a round or oblong form, longest and narrowest in *Loligo sagittata;* it is a sac with a serous and a firm fibrous tunic: the ovisacs (*fig.* 230, *a*, *a*), formed of a thin membrane derived from the general sac, are usually of an elliptical form and seem reticulate by the characteristic folding of the vitelline tunic of the ovum appearing through the transparent membrane: they are attached to one part of the ovarian cavity, as in the Nautilus. The ova and ovisacs are proportionally larger in the Decapods than the Octopods; are largest in *Sepiola*, smallest in *Argonauta.* In the Octopods there is a communication between the ovarian sac and the aquiferous pericardial cavities which open into the branchial chamber.

In *Sepia*, *Sepiola*, *Rossia*, and *Loligo vulgaris*, there is a single oviduct, with a glandular laminated outlet; and there are two distinct laminated nidamental glands on each side of its termination. In the Octopods there are two oviducts, which in *Argonauta* and *Tremoctopus* are simple; but in *Octopus* and *Eledone* are each provided with a special glandular enlargement about the middle of their course: there are no detached nidamental glands. In *Loligo sagittata* and *Onychoteuthis* there are two distinct convoluted oviducts, and two separate nidamental glands. These glands in the Cuttlefish rest upon a soft parenchymatous body, of a bright orange colour: the corresponding part is rose-coloured in *Sepiola:* it is double in *Rossia* (*fig.* 230, *i*, *i*), and the Calamaries: these bodies have no ducts, and appear to be the homologues of the suprarenal bodies in the vertebrate animals.

The subjoined illustration (*fig.* 230) of the female organs in the Cephalopoda is taken from the *Rossia.*[*] The ovarian cavity is laid open, showing the ovisacs (*a*, *a*), which are fewer in number, but relatively double the size of those in *Sepia ;* one (*b*) is in the act of shedding the ovum (*f*); others (*c*, *c*), having discharged their ovum, were collapsed and in progress of absorption. The oviduct (*d*) commences by a round aperture, and continues membranous to the terminal gland (*e*) allowing the ova (*f*, *f*) to be seen through it. The gland (*e*) consists of two semioval groups of transverse glandular lamellæ. The oviduct terminates, as in *Sepia* and *Sepiola,* on the left side, behind the orifices of the nidamental glands (*g*, *g*). These bodies are situated on the ventral aspect of the abdomen, but are attached, like their homologues in *Nautilus* and the Gastropods, to the mantle. They are each composed of a double series of transverse, parallel, close-set laminæ, the straight margins of which are free and turned towards each other, along the middle line of the gland. When this is laid open, an impacted layer of soft albuminous substance is found occupying the interspace of the two sets of laminæ; in which, in *Rossia,* it is moulded into a filamentary form, whence it escapes by the anterior orifice, as at *h*, *h*, *fig.* 230. Each supplementary body, *i*, *i*, is indented by a deep groove close to the aperture of the nidamental gland : it may assist in moulding the secretion, and applying it to the ova as they pass out. The female organs of *Spirula* are like those of *Rossia;* but I found the ova in the oviduct packed so as to lie, three or four, in the same transverse line. In the Argonauta the oviducts form several convolutions before they ascend to their termination in the branchial chamber, where, as in *Octopus,* the vulvæ are wide apart : their lining membrane has an uniform thick

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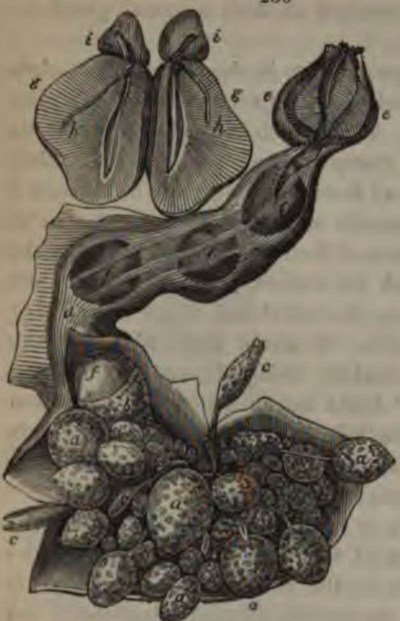

Rossia palpebrosa.

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[*] CCLXXI., and Prep. No. 2962 A.

glandular character. In the *Loligo sagittata* the oviducts commence about one-third of the length of the ovary from its anterior end; and after a short course are disposed in sixteen close, transverse folds, after which they are continued straight to their terminal glandular division.

With respect to the act of impregnation in the Cephalopods, Aristotle, whose knowledge both zoological and zootomical of this class was great, gives two accounts.[*] In the fifth book of the "Historia Animalium," he states that the *Octopus*, *Sepia* and *Loligo* copulate in the same manner; the male and female having their heads turned towards each other, and their cephalic arms being so co-adapted as to adhere by the mutual apposition of their suckers. In this act the Poulps (*Octopus*) are said to seek the bottom, while the Cuttles and Calamaries swim near the surface, the individual of one sex moving forwards and the other backwards. It would seem, also, that the modified arm of the male in certain Octopods had not escaped notice, for he adds (ch. v. 1.), "Aiunt nonnulli marem habere non nihil simile genitali in uno ex brachiis, quod duo maxima acetabula continent: id protendi quasi nervosum usque in medium brachium atque totum in infundibulum fæminæ inseri."

From the position of the vulva or vulvæ at or near the base of the funnel, and from the inclination of the penis in the Cuttle to the side corresponding to that where, in the female, the vulva opens, it is most probable that the sexes do combine as above described; but actual intromission by the vulva seems physically impossible in the Cephalopods. The males may, and probably do, introduce the spermatophores into the pallial cavity of the female: they have, in fact, been seen attached to the internal surface of this cavity, near the vulva. The male Argonaut leaves the modified spermatophorous arm attached by its suckers to the interior of the funnel or branchial chamber, whence arose the natural mistake as to its being a parasitic worm. The spermatozoa, expelled from the spermatophora while in the branchial chamber, may be conveyed either by the oviduct, or more directly by the aquiferous canals, to the ovarium: and it is certain that impregnation takes place before the ovum has passed into the oviduct and has acquired its nidamental covering.

The ovarian ova consist of a deep yellow or rose-coloured vitellus, enclosed in a delicate vitelline membrane, which is folded longitudinally in the Octopods, and both lengthwise and transversely in the Decapods, the folds penetrating the vitellus, and giving the ova a reticulate exterior. After dehiscence, and when received in the membranous part of the oviduct, the vitellus expands, the folds disappear, and the surface of the egg is smooth. There they acquire the chorion and receive additional layers of a thick albuminous matter from the gland of the oviduct, which may be compared to the shell-secreting cavity in the oviduct of the fowl. The ova are connected together in characteristic clusters by the secretion of the superadded nidamental glands when these are present.

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[*] CCCLXXVII. lib. iv. and v.

In the Argonaut the minute ova are appended by long filamentary stalks to the cavity of the involuted spire of the shell where they are hatched. In the *Tremoctopus* the chaplets of eggs are bound together in the form of a staff, by a lamellated and subgranular secretion, and are so carried, according to Kölliker, attached to one of the arms. The ova of the Calamary are enclosed in long transparent gelatinous cylindrical sheaths, and offer a close analogy to the spermatophora in the male. The ova of the Sepioteuthis are likewise enclosed in cylindrical sheaths; but these are shorter, and contain fewer ova, than in the Loligo. The eggs of the Cuttle-fish are of comparatively large size, of an oval form, attenuated at the extremities, and each enveloped in a lamellated horny covering, which is prolonged into a short cleft pedicle at one extremity, and attached by it to some foreign body: numbers of these ova are generally found clustered together, and they have commonly received the name of sea-grapes (*fig.* 231).

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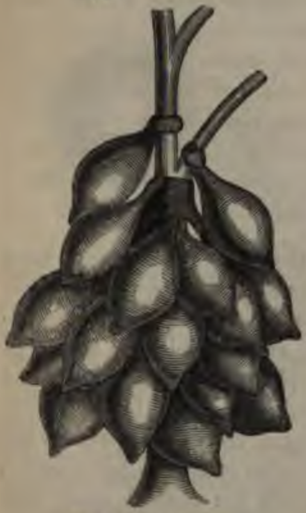

Ova of Sepia officinalis.

Of the many noble contributions to Embryology, which science owes to German physiologists, none surpass in importance that* from which the following remarks have been abridged.

At the beginning of the development of the egg, in *Sepia officinalis*, the germ-vesicle with its nucleus is surrounded by a small quantity of colourless yolk, and all the parts of the egg grow, but the germ-vesicle in a less ratio than the yolk. When the germ-vesicle has reached its full size the yolk increases and acquires its characteristic colour. The germ-vesicle advances close to the vitel-

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* CCCXCI.

line membrane near the narrower end of the egg; and, when the folds of the vitelline membrane have been obliterated in the detached egg, the germ-vesicle has disappeared or become obscured through the effect of impregnation. The influence of the resulting impregnated vesicle, or primary germ-cell, extends over only a small part of the yolk, like the cicatricula of the bird's egg. The fission of that germ-cell manifests itself by two slightly elevated prominences, as at *fig.* 232, A, *a*, in each of which is a secondary nucleated cell. The next stage shows four prominences (*ib.* B); these by their fission form eight (*ib.* C), of a triangular form, becoming more acute, and the apex of each showing the hyaline nucleus: and now spontaneous fission manifests itself in another direction, and the apices of each segment seem to be detached, each fission-sphere (*ib.* D, *a*) having, like each fission-segment (*b*), its proper nucleus. This figure shows the sixteenfold division, affecting the central cells (*a*) as well as the segments (*b*). The progressive multiplication of sperm-force-centres multiplies the peripheral segments, and fills the central space with smaller and more numerous derivative germ-spherules.

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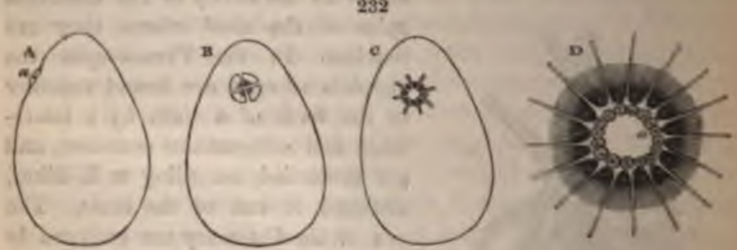

The germ-mass thus formed may be divided into two layers, and the outer surface becomes smooth. Its further increase by fission-growth and confluence of germ-cells manifests itself by slight elevations from this "cambium" (*fig.* 233); the first of these is a median rhomboid one, which is the basis of the trunk or mantle-sac (*a*); two small bean-shaped prominences (*b*) become the eyes; a linear elevation (*d*) on each side of the mantle indicates the lateral halves of the funnel. At this period the germ-mass is two lines long and subcircular. Next appear the cartilages of the funnel (*e*); then the rudiments of the gills (*c*); afterwards the anterior (*h*) and posterior (*i*) cephalic lobes and the arms, the latter beginning with the ventral pairs (1, 2); and now there is evidence of ciliary action at many parts of the embryonal surface, as, *e. g.*, on the mantle, the

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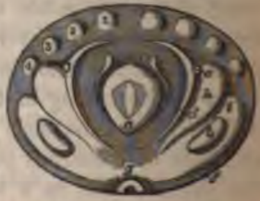

crura of the funnel, the cephalic lobes and eyes, but not in the gills. The two crura of the funnel elongate; the eyes become reniform. Two other (dorsal) pairs (3, 4) of arms appear, and now the mouth (*g*) is established as a median semilunar depression with a raised border. The mantle (which is built up from below or behind) becomes larger and more prominent, its free border begins to be detached along its ventral side, and the germinal membrane expands upon the yolk. The mouth liberates its anterior border and slides from the vitelline mass. The crura of the funnel (*fig.* 234, *d*) approximate; the small gills (ib. *c*) begin to get under the still-growing border of the mantle (*a*), and a small pulsating eminence (*m*), between the gills indicates the systemic heart. The two tentacles (2) now rise near the posterior cephalic lobes, and, from the beginning, are more slender than the ordinary arms (1, 3, 4, 5). The miniature Sepia is recognisably sketched out: but all its parts, save the gills and funnel-lobes, are ciliary. By this ciliary action the embryo Loligo rotates in its chorion; but the yolk of the Sepia is too big, and the albumen yields to the microscopic dynamic and flows over the embryonal disc. The crura of the funnel first coalesce at their dorsal margin: the gills, not yet quite covered by the mantle, begin to show their subdivisions: the eyes (ib. *b*) receive their pigment: the arms converge towards the centre of the cephalic lobes, but they show no trace of suckers: the yolk (*p*) is now almost quite surrounded by the germinal membrane (*f*). The anterior or ventral divisions of the infundibular crura lay with their free, arched, thick borders overlapping, and finally coalesce, completing the dibranchiate tubular funnel, the apex of which now reaches nearly to the base of the arms. The sepium, or internal shell (*fig.* 235, *f*), the digestive canal (*b*), with its appendages, and the ink-bag (*e*), are formed successively: the basis of the nervous system was probably coeval with the appearance of the cephalic lobes and cartilage. In the course of the investment of the yolk, and the concomitant growth of the embryo, the vitelline sac becomes constricted into an external (*c*) and an internal (*d*) portion: the constricted portion is gradually elongated, and becomes a narrow canal, extending from the head by the side of the mouth. The external yolk progressively becomes internal as the latter is absorbed, and is finally

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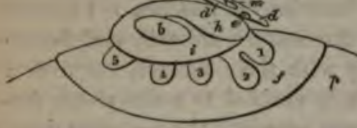

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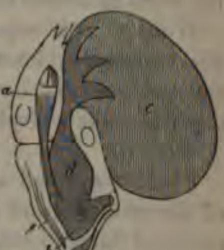

Embryo Sepia.

subdivided and disappears, whilst the intestinal canal is completed. The last remnant of the internal yolk-sac appears to be indicated in the Octopus by the anterior cæcal prolongation of the crop. At the later periods of development the respiratory movements are vigorously performed by the alternate dilatation and contraction of the mantle, and by a corresponding erection and depression of the funnel: the ink-bag (*e*) is now conspicuous by the colour of its contents, which are sufficient to blacken a considerable quantity of water, and the little Cephalopod is thus provided with the means of concealing itself from any enemy that might be prepared to devour it upon its emergence from the defensive covering of the ovum. At the period of exclusion five of the layers of the dorsal shell (*f*) of the young cuttle-fish have been formed; but, except the nucleus, which is calcified, they are horny and transparent. The lateral fins are not merely developed, but are broader than in the mature animal; and the cephalic arms are furnished, not only with their suckers, but with a basal web; so that the young Sepia is enabled to swim either forwards or backwards, and its eyes have acquired the requisite development to warn it of an approaching enemy, or direct its course to its appropriate food.

Thus in the class at the summit of the Molluscous, as in that which crowned the Articulate, series, there is no metamorphosis. The cephalopodic character is manifested long before the parts of the embryo are completed: even the dibranchiate peculiarity of the infundibular cartilages is recognisable when, as yet, only the visceral sac, the funnel, the eyes, and the gills are sketched out. No phase or form of Invertebrate existence below the Cephalopod is even transitorily manifested. Before the ciliary action is visible on the germ-mass, the parts that exhibit it bear unequivocally the cephalopodous stamp. Whilst the funnel remains ununited along the ventral aspect, whilst the arms are without suckers, and the prominent eyes unprovided with orbits, the characters of the lower order of the Cephalopoda are indeed temporarily exhibited, but the gills at no period show the tetrabranchiate condition.

Were growth superinduced at any arrested stage of Cephalopodic development, no known inferior form of Mollusk would result. No arrested stage of development of any higher animal would produce any thing like a Cephalopod.

There is so small a part of the multifarious and diversified details of the anatomy and physiology of the Invertebrata from which the practical Surgeon can directly profit, they seem so remotely connected with human physiology, the animals themselves are so different in form, in powers, in modes of life, from those which more obviously attract the interest of the anatomical Teacher, that some apology may seem necessary for the devotion of an entire course of Lectures, in the theatre of a College of Surgeons, to the lowest and most minute forms of animal life.

We learn, indeed, with little surprise, that the import of the dissections of the Invertebrate animals, by the busy care-worn practitioner who, in the last century, prepared the most instructive illustrations of these lectures, were not understood; and that these occupations of Hunter were regarded by some of his contemporaries as a kind of laborious trifling. But the question of "cui bono?" which might then be pardonable, would be inexcusable at the present day, when the relations of Surgery as a science to Physiology, and the dependence of Physiology upon Comparative Anatomy are so much better understood: and I trust that a brief retrospect of some of the deductions from the details of Invertebrate Anatomy will suffice to demonstrate their indispensable value to all who are interested in the progress of physiological science.

The Invertebrated classes include the most numerous and diversified forms of the Animal Kingdom. At the very beginning of our inquiries into their vital powers and acts we are impressed with their important relations to the maintenance of life and organisation on this planet, and their influence in purifying the sea and augmenting and enriching the land—relations of which the physiologist conversant only with the Vertebrated animals must have remained ignorant. At our first entrance, and by the lowest portal, into the vast and intricate repositories of the animal mechanisms, we are at once introduced to the phenomena of spontaneous fission and ciliary motion, of the generality and importance of which in the animal economy each day seems to bring fresh proof, but which are most conspicuously manifested in the monads.

The physiologist must have remained in ignorance of the most instructive modifications and combinations of the principal organs of the animal frame, if the researches of the Comparative Anatomist had been confined to the Vertebrated animals, or those which are constructed on the same general type as ourselves. Without a much deeper investigation, we never could have understood the relative importance of the different organs, the order of their introduction and progressive complication, their homological and analogical relations.

Only in the Invertebrated classes do we find examples in which the lungs, like the liver, are supplied by the ramifications of the trunk of a vein without the interposition of a heart. Only in the lowest of the Invertebrate animals could we have found the office of the lung performed by a vascular portion of the integument; and the Invertebrata alone could have furnished us with examples of the progressive modifications of this portion of the vascular skin, by which the breathing organ is at length definitely developed. But why specially cite the respiratory system? The earliest and most instructive forms of almost every organ, as it is variously arrested in its development and adapted to the exigencies of the mature animal, must be sought for amongst the Invertebrata.

These animals alone furnish us examples of the oscillation through the living tissues of a fluid which seems to differ but little from sea-water, and of the direct communication of the chylaqueous system with the external oceanic medium;—of the co-existence of an aquiferous with a sanguiferous system in the same animal, and the progressive development of a true vascular organisation by which the aquiferous channels are at length superseded; — of a circulation of the blood without a heart, and of a circulation aided by the hundred-fold repetition of the propelling reservoir in the same individual;—of the meandering of the circulating fluid back to the heart through diffused venous lakes, instead of cylindrical canals. Only the low organised Invertebrate animal could have revealed to us the actual existence in nature of a condition of the blood's motion, once erroneously held to be universal, viz., its flux and reflux in the same vessels, from trunks to branches and from branches to trunks, to and from the heart*, as Aristotle conceived to be the nature of the blood's movement in all animals, and which he illustrated by the analogy of the tides of the Euripus!

In the Invertebrate series we can contemplate the most simple and essential condition of the nervous system, — a ganglion with radiated internuntiate chords,—a centre for the reception and transmission of stimuli. In this series we see such centres multiplied and set apart for different segments, or for different organs of the body. Of such arrangements, the anatomist of the Vertebrata exclusively could have formed no adequate conception. And not only are the conditions for the performance of the most essential function of the nervous system,—viz. the working of the muscular machinery agreeably with impressions received from external objects, independently of any consciousness of such changes, or of any choice and volition in the mode of remedying or avoiding them, — most plainly set forth in the Invertebrate types of the nervous system; but they afford the best subjects for illustrating that primary function by experiment.†

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* Lecture XX. TUNICATA, p. 469.

† Lecture XVI. INSECTA, p. 364.

The relation of the physical defence of an animal by shells or crusts to the low condition of the sentient system is most strikingly manifested in the Invertebrate series, and could be but feebly discerned in the higher animals, none of which exhibit the external or dermal skeleton modified to encase the limbs and form the levers and fulcra of the moving powers. The defence of the crab and oyster by dense and impenetrable armour as a compensation for their lack of intelligence and defective powers of action, reminds one of the condition of the soldier in the early and ruder states of the art of war.

If the structure and functions of the human mechanism had been illustrated only by comparison with those of other Vertebrata, the physiologist would have been acquainted with only one leading modification of the generative system in the Animal Kingdom, namely, the diœcious or bisexual. The analogy between animals and plants in the modes of continuing the species is fully illustrated only by the Invertebrata. Here the anatomist finds the self-sufficing combination of fertilising and productive organs in the same individual, as in most flowers. Other Invertebrata present the still more remarkable combination of male and female parts arranged for reciprocal union. The closer and more remarkable analogy with the vegetable kingdom offered by that peculiar modification of the generative system, in which we found the oviduct and vulva exclusively destined for the transmission of the moving particles of the fertilising fluid, the fertilised ova escaping into the abdomen by dehiscence of the ovarium, so that extra-uterine gestation was a natural and constant phenomenon, was demonstrated by dissection of the earthworm. The small transparent vermiform parasites have afforded the best subjects for the demonstration of the entry of the fertilising principle into the ovum, and of the first changes therein and thereby operated.

The diversified structures of the Invertebrate animals not only teach us the most remarkable modes of action, and instructive modifications and correlations of individual organs and systems, but they lead to an insight into, and can alone furnish the demonstrations of, the most important generalisations in zootomical science.

Of that which I have termed "the law of vegetative or irrelative repetition," by which is meant the multiplication of organs performing the same function, and not related to each other by combination of powers for the performance of a higher function, the Invertebrata afford the most numerous and striking illustrations.

Almost every organ of the body illustrates this vegetative condition at its first appearance in the Animal Kingdom. A stomach or assimilative sac is the most general characteristic of an animal.

Such sacs are developed in great numbers in the body of the Polygastrian, but each sac performs the same share of the digestive function, irrespective of the rest. The case is very different in the ruminant animal, in which each of the four stomachs has its appropriate office, and all combine together to produce a more efficient act of digestion.

The organs of generation, the next essential parts of the mere animal, when first definitely introduced with their characteristic complications in the low organised Entozoa, illustrate more forcibly the law of irrelative repetition.

We trace the definite development of the heart and gills in the Anellids, in some species of which both organs are irrelatively repeated above a hundred times. And when these, like most of the vegetative organs, assume a more concentrated form in the Molluscous series, we perceive in the structure and relations of the two auricles of the bivalve as compared with the single auricle of the univalve, and of the four gills of the Nautilus as compared with the two gills with their more perfect circulation in the Sepia, that plurality is but a sign of inferiority of condition.

When locomotive and prehensile appendages first make their appearance in free animals, they are simple, soft, and unjointed, but they are developed by hundreds, as in the Asterias and Echinus: they manifest the principle of vegetative repetition to a remarkable extent when they are developed into symmetrical pairs of setigerous tubercles in the Anellids, and even when they first appear as jointed limbs in the Myriapods: but as they become progressively perfected, varied, and specialised, they are reduced to ten in Crustaceans, to eight in Arachnids, and to six in Insects. We have just seen that the same law prevails in the introduction of the analogous cephalic organs of locomotion and prehension in the Mollusks. It is beautifully illustrated in the introduction of the organ of vision into the Animal Kingdom.

The numerous ganglions, nerves, and muscles, called forth by the vegetative succession of the segments of the body and their locomotive appendages in the Articulates, have sometimes been adduced as invalidating the claims of the Mammalia to be regarded as of higher or more complex organisation[*]; but when the law of irrelative repetition is rightly understood, the multiplication of similar parts for the repetition of the same actions is at once appreciated as essentially the more simple, as well as the inferior, condition, compared with the assemblage of less numerous parts in the same body with different offices, and with prospective arrangements that enable them to combine their different powers for definite ends.

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[*] Thus the acute philosopher YOUNG writes :—"There are even living beings, visible to the microscope, of which a million million would not make up the bulk of a common grain of sand. But it is still more remarkable, that, as far as we can discover, many of these animalcules are as complicated in their structure as an elephant and a whale. It is true that the physiology of the various classes of animals is somewhat more simple as they deviate more from the form of quadrupeds and from that of the human species; and some of the lower classes appear to approxi-

The lowest Invertebrata resemble locomotive cells: they propagate by spontaneous fission and grow by assimilation; sometimes they exhibit their geometrically multiplied divisions to a certain extent within a common capsule. The earliest phenomena in the development of the mammiferous ovum most closely resemble the common mode of multiplication of the Gonium and Volvox. Like phenomena have been observed in the vitelline germ of the frog and the fish. But the universality of the phenomena of spontaneous division, of the fissiparous procreation of nucleated cells, and of their growth by assimilation and coalescence round definite centres, as the properties of the primordial germ in all animals which produce the most conspicuous changes in the yolk, has been mainly established by collecting the observations that have been made upon the development of the embryo in the different classes of Invertebrata, and by the comparison of these with the analogous phenomena observed in the development of certain Vertebrata which we may conclude to characterise the first step in the formation of the human embryo.

And since later observations have established what I believe myself to have first observed, and suggested to be a general property of the blood-cell, — viz. its power of spontaneous subdivision into smaller centres prior to its solution[*], it is highly probable that the preliminary steps to its conversion are the same as those of the nucleated cell which constitutes the germ of the entire animal; and the proposition that the phenomena of spontaneous fission, of which the Monads offer the most conspicuous examples, are the most

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mate very much to the nature of the vegetable world. But there are single instances that seem wholly to destroy this gradation. Lyonnet has discovered a far greater variety of parts in the caterpillar of the willow-butterfly than we can observe in many animals of the largest dimensions; and amongst the microscopic insects in particular, we see a prodigality of machinery, subservient to the various purposes of the contracted life of the little animal, in the structure of which nature appears to be ostentatious of her power of giving perfection to her minutest works." —YOUNG'S *Lectures on Natural Philosophy*, 4to., p. 608. My predecessor in the Hunterian chair adopted the same view. "There are 500 muscles attached to this hard ring, which passes round the body of the Willow-caterpillar, each muscle having its nerve. Now, if I take this opportunity of making a comparison, let me ask whether there be any part of man which presents a complication equal to this?"—SIR CHARLES BELL, *Hunterian Lectures*, *Lancet*, 1833, p. 284.

[*] Medical Gazette, November 13. 1839. Dr. Martin Barry's Paper in Philos. Transactions, 1840.

universal and important in the operations of the living animal, ceases to wear the aspect of exaggeration.

It is, however, certain that the most extraordinary consequences of the fissiparous property of the nucleated cell are unknown in the Vertebrated classes, of which generation without fecundation of the procreating individual is an example. This phenomenon, which at first so much astonished and perplexed physiologists, as observed only in the Aphides, becomes intelligible and reducible to general law, and is extensively manifested in the Invertebrate series of animals.

The Monad divides itself before our eyes, constituting two, then four, next eight individuals, and so on. The impregnated germinal vesicle, which the Monad permanently represents in nature, propagates, in like manner, by spontaneous fission and assimilation, a number of impregnated cells like itself. Most of these cells are metamorphosed into the tissues of the growing embryo, but not necessarily all. Certain nucleated cells, the progeny of the primordial one, and inheriting its powers, may become, without further stimulus, the centres of development of processes like those which have built up the body that contains them: they may bud forth from the stem of the Hydra, and form new individuals by the process of gemmation; they may bud forth, in like manner, from the larval polype of the Medusa, which thereby procreates in its immature, and, as it seems, virgin state, like the wingless larvæ of the summer Aphides; they may enter the unimpregnated oviducts of these insects, and be there developed in the manner which has already been described.*

Did time permit, I might easily multiply the instances from the Invertebrate organisations, which bear directly on the establishment of the most important general laws in physiology. I shall conclude by adverting to one which is alike interesting to the anatomist and naturalist, and which has exercised the powers of the most active and enquiring intellects of the present age. To the disquisitions and discussions in which Goethe, Oken, Cuvier, and Geoffroy have taken part, the doctrines of Morphology and of Unity of Organisation owe their existence.

Some of the medical acquaintances of John Hunter, who, we are told, complacently apostrophised his pursuits in the language of pity, when they found him dissecting a snail, a bee, or a worm, little dreamt of the expanded views of the animal organisation at which he was obtaining glimpses through those narrow casements. It would seem that Hunter himself was oppressed with the vastness of the prospect, with the grandeur of the generalisations which his investigations of the lower animals, and of the embryonic forms of the higher ones, were forcing upon his reflective mind, if we may judge from his struggles to express ideas, at that period so novel, and to which he could but give imperfect utterance. "If we were capable," he says, "of following the progress of increase of the number of the parts of the most perfect animal, as they first formed in succession, from the very first, to its state of full perfection, we should probably be able to compare it with some one of the incomplete animals themselves, of every order of animals in the creation, being at no stage different from some of those inferior orders; or, in other words, if we were to take a series of animals from the more imperfect to the perfect, we should probably find an imperfect animal corresponding with some stage of the most perfect." [*]

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* Lecture XVIII. INSECTA, p. 387.

With the great accession of facts with which Comparative Anatomy has since been enriched, particularly from monographs detailing dissections of the Invertebrate animals, we may now attempt a more exact enunciation of the resemblance which a higher organised animal presents to those of a lower order in its progress to maturity: and the consequent extent to which the law of "Unity of Organisation" may be justly, and without perversion of terms, be predicated of animal structures. We shall see some grounds for the statement that the more perfect animal is at no stage of its development different from some of the inferior species; but we shall obtain proof that such correspondence does not extend to every order of animals in the creation.[†]

The extent to which the resemblance, expressed by the term "Unity of Organisation," may be traced between the higher and lower organised animals, bears an inverse ratio to their approximation to maturity.

All animals resemble each other at the earliest period of their development, which commences with the manifestation of the assimilative and fissiparous properties of the polygastric animalcule: the potential germ of the Mammal can be compared, in form and vital actions, with the Monad alone; and, at this period, unity of organisation may be predicated of the two extremes of the Animal Kingdom.[‡] The germ of the Polype acquires more conspicuously the locomotive organs of the Monad, — the superficial vibratile cilia, — before it takes on its special radiated type. The Acalephe passes through both the Infusorial and Polype stages, and propagates by gemmation, as well as spontaneous fission, before it acquires its mature form and sexual organs. The fulness of the unity of organisation which prevails through the Polypes and larval Acalephes, is diminished as the latter approach maturity and assume their special form.

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[*] Hunterian MS. quoted in my 'Physiological Catalogue,' X, vol. i. p. 4.

[†] This proposition is well supported and illustrated by Von Baer, CLXXXIX. and CCLXX.

[‡] V. Baer, not recognising this phase of germ-life, affirms that "the Vertebrata cannot descend to the lowest grades of organisation," and that their embryos pass through no permanent forms of animals whatsoever.

The Bryozoa, after simulating the higher Infusoria by their spheroid shape and active movements, due to well-developed zones or lobes of conspicuous vibratile cilia, mask their low molluscous character beneath the polype form. The Ascidian Mollusks typify more feebly and transiently the polype state in passing from that of the cercariform ciliated larva to the more special molluscous form. The Univalves and Bivalves obey the law of unity of organisation in the spontaneous fissions of their amorphous germ, and in its ciliated epithelium, by which it gyrates in the ovum; but they proceed at once to assume the molluscous type without taking on that of the Polype; the Bivalve retaining the acephalous condition, the Univalve ascending in its development to the acquisition of its appropriate head, jaws, and organs of sense.

Thus all mollusks are at one period like Monads, at another are Acephalous; but few typify the Polypes, and none the Acalephes, or Echinoderms. In the Encephalous division we meet with many interesting examples of the prevalence of unity of organisation at early periods, which is lost in the diversity of the special forms as development proceeds. Thus the embryos of the various orders of Gastropods are first abranchiate, next nudibranchiate, but only a few retain that condition of the respiratory system through life; most of them move at first by aliform anterior lobes, like those which characterise the mature Pteropods, but afterwards exchange the swimming organs for the repent disc which marks their class. The naked Gastropods are at first univalve Mollusks, like the great bulk of the class at all periods. The testaceous Cephalopods first construct an unilocular shell, which is the common persistent form in Gastropods, the Polythalamia afterwards superadd the characteristic chambers and siphon. This simple fact would of itself have disproved the theory of 'evolution,' if other observations of the phenomena of development had not long since rendered that once favourite doctrine untenable.

Thus, as we trace the development of the Molluscous animal, we find the application of the term unity of organisation progressively narrowed as development advances: for whilst all Mollusks manifest, at their earliest and most transitory period, a resemblance to the lowest or monadiform zoophytes, only the lowest order of Mollusks in the next stage of development represents the polypes; and all analogy to the radiated type is afterwards lost, until we reach the summit of the Molluscous series, when we find it interestingly, though illusively, sketched by the crown of locomotive and prehensile organs upon the head of the Cephalopods.*

In the great Articulated branch of the Animal Kingdom, there is unity of organisation with the Molluscous series at the earliest periods of development, in so far as the germ divides and subdivides and multiplies itself; but the correspondence rarely extends to the acquisition by the nascent articulate animal of the locomotive power by superficial vibratile cilia: in the great majority of the province the progeny of the fissiparous primitive germ-cell begin at once to arrange themselves into the form of the Vibrio or apodal worm, while those of the Molluscous germ diverge into the polype-form or into a more special type.

Unity of organisation prevails through a very great proportion of the Articulate series in reference to their primitive condition as apodal worms. Only in the higher Arachnids, the nucleated cells are aggregated under a form more nearly like that of the mature animal, before they are metamorphosed into its several tissues. In lower or more vermiform Condylopods, the rudimental conditions of the locomotive appendages, which are retained in the Anellides and the lower Crustaceans, are passed through in the progress of the development of the complex-jointed limbs. In the great series of air-breathing insects, we have seen that the diverging branch of the Myriapods manifests at an early period the prevailing hexapod type, and that all Insects are at first apterous, and acquire the jointed legs before the wings are fully developed. An articulate animal never passes through the form of the Polype, the Acalephe, the Echinoderm, or the Mollusk†: it is obedient to the law of unity of organisation only in its monad stage: on quitting this, it manifests the next widest relations of uniformity as a Vibrio or apodal worm; after which the exact expression of the law must be progressively contracted in its application as the various Articulata progressively diverge to their special types in the acquisition of their mature forms.

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* Von Baer believed that the head completely represented the radiate type, the molluscous structure being seen only on the sac-like part of the body. He remarks, "the Cephalopoda most frequently swim with their heads downwards; the radiate portion of the body therefore seems to hold and to move itself in accordance with the mode of locomotion prevalent in its type, overcoming the tendency of the molluscous body."—CLXXXIX. p. 760. I have always regarded this supposed combination of the two types as illusory.

† CLXXXIX. p. 753.

In the proper Radiated series itself we discern the same principle: the radiated type culminates in the Echinoderms; but the most typical forms, called emphatically star-fishes, are pedunculated in the embryo-state, at least in one family, and so far manifest conformity of organisation with the Polypes and the vast and almost extinct tribes of the Pentacrinites, before acquiring their free and locomotive maturity.

It will be found when we enter upon the consideration of the development of the Vertebrate embryo, that its unity of organisation with the Invertebrata is restricted to as narrow and transitory a point as that of the Articulate with the Molluscous series. Manifesting the same monad-like properties of the germ, the fissiparous products proceed to arrange and metamorphose themselves into a vermiform apodal organism, distinguished from the corresponding stage of the Insect by the Vertebrate characteristics of the nervous centres,—viz. the spinal chord and its dorsal position; whereby it is more justly comparable to the apodal fish than to the worm.

Thus every animal in the course of its development represents some of the permanent forms of animals inferior to itself; but it does not successively repeat them all, nor acquire the organisation of any of the inferior forms which it transitorily typifies. Had the Animal Kingdom constituted, as was once supposed, a single and continuous chain of Being progressively ascending from the Monad to the Man, unity of organisation might then have been demonstrated to the extent in which the theory has been maintained by the disciples of the school of Bonnet and Geoffroy St. Hilaire.

There is only one organic form which is either permanently or transitorily represented throughout the Animal Kingdom: it is that of the microscopic infusorial Monad, with the consideration of which the present survey of the Invertebrate animals was commenced, and which is to be regarded as the fundamental or primary form.

Other forms are represented less exclusively in the development of the Animal Kingdom, and may be regarded as secondary forms. These are, the Polype, the Worm, the Tunicary, and the Lamprey; they are secondary in relation to the Animal Kingdom at large, but are primary in respect of the primary divisions or provinces.*

Thus the *Radiata*, after having passed through the monad-stage, enter that of the polype; many there find their final development; others proceed to be metamorphosed into the Acalephe or the Echinoderm.

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* Von Baer adopted Cuvier's view of four leading types—Radiate or "peripheral," Articulated or "longitudinal," Molluscous or "massive," and Vertebrate: but he superadded the idea that the Vertebrate type united in itself the three others, "the head being an outline of the radiate type." CLXXXIX. p. 746. Here, however, an unreal signification seems to be assigned to the "circulus arteriosus" and its four vascular trunks.

The *Articulata*, at an early stage of their development, assume the form or condition of the apodal and acephalous worm; some find their mature development at that stage, as the parasitic Entozoa; others proceed to acquire annulations, a head, rudimental feet, jointed feet, and finally wings: radiating in various directions and degrees from the primary or fundamental form of their sub-kingdom.

The *Mollusca* pass from the condition of the ciliated Monad to that of the shell-less Acephalan, and in like manner either remain to work out the perfections of that stage, or diverge to achieve the development of shells, of a head, of a pair of fins, of a ventral foot, or of cephalic arms, with all the complexities of organisation which have been demonstrated in the concluding Lectures of this Course.

The *Vertebrated* germ having manifested its monadiform relations by the spontaneous fission, growth, and multiplication of the primordial nucleated cells, next assumes, by their metamorphosis and primary arrangement, the form and condition of the finless cartilaginous fish, from which fundamental form development radiates in as many and diversified directions and extents, and attains more extraordinary heights of complication and perfection than any of the lower secondary types appear to be susceptible of. The ultimate stages of these developments, the various permanent or mature structures of the Vertebrated series, with their physiological and other relations, will form the subjects of succeeding lectures.

CLASS CEPHALOPODA.

Encephalous mollusks, with locomotive and prehensile organs radiating from the head: diœcious and ametabolian.

Order TETRABRANCHIATA.

With four gills: no ink-bladder. Shell external, camerated and siphonated.

Family *Nautilidæ*. Shell discoid or spiral; dwelling-chamber large; aperture simple; sutures simple; siphon simple, central, or near the concavity of the shell-curve.

Genera *Nautilus, Aturia, Discites, Temnocheilus, Cryptoceras, Lituites, Trochoceras, Clymenia.*

Family *Orthoceratidæ*. Shell straight, curved, or discoidal; dwelling-chamber small; aperture contracted; siphon central, wide, or complex.

Genera *Orthoceras, Cameroceras, Actinoceras, Ormoceras, Huronia, Endoceras, Gomphoceras, Onchoceras, Phragmoceras, Cyrtoceras, Gyroceras, Ascoceras.*

Family *Ammonitidæ*. Shell discoidal, curved, spiral, or straight; dwelling-chamber elongated; aperture guarded by processes and closed by an operculum (called *Trigonellates* and *Aptychus*); sutures angulated, or lobed and foliated; siphon peripheral, or at the convexity in the curved shells.

Genera *Goniatites, Ceratites, Ammonites, Crioceras, Toxoceras, Ancyloceras, Scaphites, Helicoceras, Turrilites, Hamites, Ptychoceras, Baculites.*

Order DIBRANCHIATA.

With two gills; an ink-bladder. Shell commonly internal and rudimentary.

Tribe DECAPODA.

Family *Spirulidæ.* Shell chiefly internal, nacreous; whorls separate, chambered; siphon near the concavity of the shell-curve.

Genus *Spirula.*

Family *Belemnitidæ.* Shell internal, consisting of a "phragmocone" with a marginal siphon, lodged in a "guard," sometimes produced into a horny plate or "pen."

Genera *Belemnites, Belemnitella, Belemnoteuthis, Conoteuthis.*

Family *Sepiadæ.* Shell internal, consisting of a flattened "phragmocone," lodged in an open "guard," prolonged behind into a "mucro."

Genera *Sepia, Beloptera, Belemnosis.*

Family *Teuthidæ.* Shell internal, simple, wholly or in great part horny, called "gladius" or "pen."

Genera *Coccoteuthis, Enoploteuthis, Onychoteuthis, Histioteuthis, Cheiroteuthis, Loligo, Loligopsis, Cranchia, Rossia, Sepiola, Sepioteuthis, Leptoteuthis, Geoteuthis, Beloteuthis.*

Tribe OCTOPODA.

Family *Pinnata.* Shell rudimental, internal, uncalcified: a pair of pallial fins.

Genera *Sciadephorus, Pinnoctopus.*

Family *Nuda.* Shell rudimental, internal, uncalcified. No pallial fins.

Genera *Octopus, Tremoctopus, Eledone.*

Family *Testacea.* Shell calcareous, simple, external, peculiar to the female. No pallial fins.

Genus *Argonauta.*

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GLOSSARY

OF ANATOMICAL AND OTHER SCIENTIFIC TERMS USED IN THESE LECTURES.

Abdomen. (Lat. *abdo*, I conceal.) The posterior and principal cavity containing the bowels and many other viscera of the animal. The abdomen is distinct from the thorax in crustaceans, spiders, and insects.

Abdominales. (Lat. *abdomen*.) An order of fishes, so called from the attachment of the ventral fins to the abdomen behind the pectorals.

Aberrant. (Lat. *aberro*, I wander from.) This term is applied to those species which deviate most from the type of their natural group.

Abranchiate. (Gr. *a*, without; *bragchia*, gills.) When an animal is devoid of gills.

Acalepha. (Gr. *akalephe*, a nettle.) The class of radiated animals with soft skins, which have the property of stinging like a nettle.

Acalephoid. Like a Medusa or other common form of Acalepha.

Acanthocephala. (Gr. *akanthos*, a spine; *kephale*, a head.) The order of intestinal worms having the head armed with spines or hooks.

Acarus. (Gr. *akari*, a mite.) The name of a genus of Arachnida, to which the cheese-mite and allied species belong.

Acaridæ. The family of which the genus *Acarus* is the type.

Acasta. (Gr. *akaste*.) A name arbitrarily applied to a genus of Barnacles, parasitic upon sponges.

Acephalous. (Gr. *a*, without; *kephale*, head.) Headless. The animals in which a distinct head is never developed.

Acephalocyst. The parasitic hydatid, which consists of a cyst or bag without a head.

Acetabula. (Lat *acetabulum*, a shallow cup.) The fleshy sucking-cups with which many of the invertebrate animals are provided.

Acini. (Lat. *acinum*, a berry.) The secerning parts of glands, when they are suspended like grains or small berries to a slender stem.

Acoustic. (Gr. *akouo*, I hear.) Appertaining to sound, or the organ of hearing.

Acrita. (Gr. *akritos*, confused.) A term applied to the lowest animals, in which the organs, and especially the nervous system, were supposed to be confusedly blended with the other tissues.

Actinia. (Gr. *aktin*, a ray.) The genus of Polypes, which have many arms radiating from around the mouth.

Actinoceros. (Gr. *aktin*, a ray; *keras*, a horn.) A generic term, signifying the radiated disposition of parts like horns.

Adipose. (Lat. *adeps*, fat.) Fatty.

Akera. (Gr. *a*, without; *keras*, a horn.) The family of Mollusca, without horns or feelers.

Alar. (Lat. *ala*, a wing.) Belonging to a wing.

Albuminiparous. A part, gland, or surface which secretes albumen.

Albuminous. (Lat. *albumen*, white of egg.) Consisting of albumen, or the substance which forms the white of an egg.

Aliform. Shaped like a wing.

Alternate generation. That modification of generation in which the young do not resemble the parent, but the grand-parent; so that the successive series of individuals seem to represent two species alternately reproduced, in which also parthenogenesis alternates with the ordinary engendering by impregnation.

Alula. A little wing.

Ambulacra. (Lat. *ambulacrum*, an avenue or place for walking.) The perforated series of plates in the shell of the sea-star or sea-urchin.

Ambulatory. (Lat. *ambulo*, I walk.) An animal or a limb made for walking.

Ammonites. An extinct genus of Mollusca, allied to the Nautilus, which inhabited a chambered shell, called Ammonite from its resemblance to the horns on the statues of Jupiter Ammon.

Amorphous. (Gr. *a*, without; *morphe*, form.) Bodies devoid of regular form.

Amphipods. (Gr. *amphi*, on both sides; *pous*, a foot.) The order of Crustacea, which have feet for both walking and swimming.

Amphistoma. (Gr. *amphi*; *stoma*, a mouth.) The genus of suctorial parasitic worms, which have pores like mouths at both ends of the body.

Ampulla. (Lat. a bottle.) A membranous bag, shaped like a leathern bottle.

Anaima. (Gr. *a*, without; *aima*, blood.) The name given by Aristotle to the animals which have no red blood, and which he supposed to be without blood.

Analogue. A part or organ in one animal which has the same function as another part or organ in a different animal. *See* Homologue.

Anastomose. (Gr. *ana*, through; *stoma*, mouth.) When the mouths of two vessels come into contact and blend together, or when two vessels unite as if such kind of union had taken place.

Androgynous. (Gr. *anèr*, a man; *gunè*, a woman.) The combination of male and female parts in the same individual.

Anellata. (Lat. *annellus*, a little ring.) The worms in which the body seems to be composed of a succession of little rings, characterised by their red blood.

Anellide. The anglicised singular of *Anellata*.

Anenterous. (Gr. *a*, without; *enteron*, a bowel.) Animals which have no intestinal canal.

Annulated. (Lat. *annulus*, a ring.) When an animal or part appears to be composed of a succession of rings.

Anourous. (Gr. *a*, without; *oura*, a tail.) Tail-less.

Antenna. (From the Latin for yard-arm.) Applied to the jointed feelers or horns upon the heads of insects and crustacea, and sometimes to the analogous parts, which are not jointed in worms and other animals.

Anthozoa. (Gr. *anthos*, a flower; *zoon*, an animal.) The class of Polypes, including the actinia and allied species, commonly called animal-flowers.

Antiperistaltic. (Gr. *anti*, against; and *peristaltic*.) When the vermicular contractions of a muscular tube follow each other in a direction the reverse of the ordinary one.

Antlia. (From the Latin for pump.) Restrictively applied to the spiral instrument of the mouth of butterflies and allied insects, by which they pump up the juices of plants.

Aorta. (Gr. *aorte*, the wind-pipe; and also the name of the great vessel springing from the heart, which is the trunk of the systemic arteries.) It is exclusively applied in the latter sense in modern anatomy.

Aphidian. Belonging to the insect called *aphis*, or plant-louse.

Apical. (Lat. *apex*, the top of a cone.) Belonging to the pointed end of a cone-shaped body.

Apodal. (Gr. *a*, without; *poda*, feet.) Footless; without feet or locomotive organs: fishes are so called which have no ventral fins.

Apterous. (Gr. *a*, without; *pteron*, a wing.) Wingless species of Insects or Birds.

Arachnida. (Gr. *arachne*, a spider.) Spiders, and the animals allied to them in structure.

Arborescent. (Lat. *arbor*, a tree.) Branched like a tree.

Arthrodial. (Gr. *arthron*, a joint.) It is restricted to that form of joint in which a ball is received into a shallow cup.

Articulata. (Lat. *articulus*, a joint.) Animals with external jointed skeletons or jointed limbs.

Ascidian. (Gr. *askos*, a bottle.) The shell-less acephalous Mollusks, which are shaped like a leathern bottle.

Assimilation. (Lat. *assimilatio.*) The act by which organised bodies incorporate foreign molecules and convert them into their own proper substance.

Astomatous. (Gr. *a*, without; *stoma*, a mouth.) Certain Infusoria which have no true or determinate mouth.

Atol. The name given by the Polynesians to certain forms of coral islands.

Automatic. (Gr. *automatos*, self-moving.) A movement in a living body without the intervention or excitement of the will.

Axilla (from the Latin for armpit); and applied to other parts of the animal body which form a similar angle.

Azygos. (Gr. *a*, without; *zugos*, yoke.) Single, without fellow.

Baculite. An extinct genus of molluscous animals allied to the Nautilus, which inhabited a straight-chambered shell, resembling a staff; whence the name of the genus, from *baculus*, a staff.

Balanoids. (Gr. *balanos*, an acorn.) A family of sessile Cirripeds, the shells of which are commonly called acorn-shells.

Basilar. (Lat. *basis*, a base.) Belonging to the base of the skull.

Batrachia. (Gr. *batrachos*, a frog.) The order of reptiles including the frog.

Belemnite. (Gr. *belemnon*, a dart.) An extinct genius of molluscous animals allied to the sepia, and provided with a long, straight, chambered, conical shell in the interior of the body.

Bifid. Cleft into two parts, or forked.

Bifurcate. Divided into two prongs or forks.

Bilateral. Having two symmetrical sides.

Bilobed. Divided into two lobes.

Bipartite. Divided into two parts.

Biramous. A limb which forks into two oar-like extremities.

Bituberculate. With two knobs or tubercles.

Bivalve. When a shell consists of two parts, closing like a double door. The Mollusca, so protected, are commonly called bivalves.

Bothriocephalus. (Gr. *bothros*, a pit; *kephale*, a head.) The genus of tape-worms with depressions on the head.

Botrylli. (Gr. *botrus*, a bunch of grapes.) A little cluster of berry-shaped bodies.

Brachial. (Gr. *brachion*, the arm.) Belonging to the arm.

Brachiopoda. (Gr. *brachion*; *poda*, feet.) A class of acephalous Mollusca, with two long spiral fleshy arms continued from the side of the mouth.

Brachyura. (Gr. *brachus*, short; *oura*, tail.) The tribe of Crustacea with short tails, as the crabs.

Brachyurous. Short tailed; usually restricted to the Crustacea.

Branchia. (Gr. *bragchia*, the gills of a fish.) The respiratory organs which extract the oxygen from air contained in water.

Branchiopods. (Gr. *bragchia*, gills; *poda*, feet.) Crustacea in which the feet support the gills.

Bryozoa. (Gr. *bruon*, moss; *zoon*, animal.) A class of highly-organised Polypes, most of the species of which incrust other animals or bodies like moss.

Buccal. (Lat. *bucca*, mouth or cheeks.) Belonging to the mouth.

Byssus (from the Greek word, signifying the silky filaments which project from the bivalve called Pinna). Applied to the analogous parts in other Mollusks.

Cæcum and **Cæca.** (Lat. *cæcus*, blind.) A blind tube, or productions of a tube which terminate in closed ends.

Canthus. (Gr. (*kanthos.*)) The corner of the eye.

Capitate. (Lat. *caput*, head.) When a part is terminated by a knob like the head of a pin.

Carapace. The upper shell of the crab or tortoise.

Cardia. (Gr. *kardia*, the heart or stomach.) The opening which admits the food into the stomach; also the region called the pit of the stomach.

Carnivorous. (Lat. *caro*, flesh; *voro*, I devour.) The animals which feed on flesh.

Caruncle. (Lat. *caruncula.*) A soft wart-like eminence.

Caudal. (Lat. *cauda*, a tail.) Belonging to the tail.

Cauda Equina. The brush of nerves which terminates the spinal marrow in the human subject, and the homologous part in the lower animals.

Cellular tissue. (Lat. *cella*, a cell.) The elastic connecting tissue of the different parts of the body, which every where forms cells or interspaces containing fluid.

Centipede. (Lat. *centum*, a hundred; *pes*, a foot.) A genus of insects with very numerous feet.

Cephalo-thorax. (Gr. *kephale*, head; *thorax*, chest.) The anterior division of the body in spiders, scorpions, &c., which consists of the head and chest blended together.

Cephalic. (Gr. *kephale*, head.) Belonging to the head.

Cephalopoda. (Gr. *kephale*; *poda*, feet.) The class of molluscous animals in which long prehensile processes or feet project from the head.

Cercariæ. (Gr. *kerkos*, a tail.) The animalcules whose body is terminated by a tail-like appendage.

Cercariform. Shaped like Cercariæ.

Cercæ. (Gr. *kerkos*, a tail.) The feelers which project from the hind part of the body in some insects.

Cerealia. (*Ceres*, the Goddess of corn.) The name of the natural family of plants which produce corn, oats, rye, &c.

Cestoidea. (Gr. *kestos*, a girdle.) The order of intestinal worms with long and flat bodies like tape, usually called tape-worms.

Chelonia. (Gr. *chelone*, a turtle.) The order of reptiles including the tortoises and turtles.

Chelæ. (Gr. *chele*, a claw.) Applied to the bifid claws of the Crustacea, scorpions, &c.

Chelicera. (Gr. *chele*, a claw; *keras*, a horn.) The prehensile claws of the scorpion, which are the homologues of antennæ.

Chilognatha. (Gr. *cheilos*, a lip; *gnathos*, a jaw.) The order of many-footed insects typified by the Gally-worm or Iulus.

Chilopoda. (Gr. *cheilos*, a lip; *poda*, feet.) An order of many-footed insects typified by the Centipede.

Chitine. (Gr. *chiton*, a coat.) The peculiar chemical principle which forms the integument of insects.

Chlorophyll. (Gr. *chloros*, light green; *phyllos*, a leaf.) The colouring matter of the leaves and some other parts of plants.

Choledochus. (Gr. *cholè*, bile; *dòche*, receptacle.) The tube formed by the union of the hepatic and cystic ducts.

Chorion. From the Greek word signifying the membrane which encloses the fœtus and applied generally to the outer covering of the ovum.

Chrysalids. (Gr. *chrusos*, gold.) The stage of the butterfly immediately preceding its period of flight, when it is passive, and enclosed in a case which sometimes glitters like gold.

Chyle. (Gr. *chulos*, juice.) The nutrient fluid extracted from the digested food by the action of the bile.

Chyme. (Gr. *chumos*, juice.) The digested food which passes from the stomach into the intestines.

Cicatrix. From the Latin, signifying scar.

Cilia. (Lat. *cilium*, an eyelash.) The microscopic hair-like bodies which cause, by their vibratile action, currents in the contiguous fluid, or a motion of the body to which they are attached.

Ciliated. Provided with vibratile cilia.

Ciliobrachiata. The class of Polypes in which the arms are provided with vibratile cilia.

Ciliogrades. (Lat. *cilium*; and *gradior*, I walk.) The order of Acalephæ which swim by the action of cilia.

Circumgyrations. (Lat. *circum*, around; *gyrus*, a circle.) Motions in a circle.

Cirri. (Lat. *cirrus*, a curl.) The curled filamentary appendages, as the feet of the barnacles.

Cirrigerous. Supporting cirri.

Cirrigrades. Moving by cirri.

Cirripeds or Cirripedia. (Lat. *cirrus*, a curl; *pes*, a foot.) A class of articulate animals having curled jointed feet. Sometimes written *Cirrhipedia* and *Cirrhopoda*.

Clavate. (Lat. *clavus*, a club.) Club-shaped; linear at the base, but growing gradually thicker towards the end.

Cloaca. (Lat. *cloaca*, a sink.) The cavity common to the termination of the intestinal, urinary, and generative tubes.

Clypeiform. (Lat. *clypeus*, a shield; *forma*, shape.) Shield-shaped; applied to the large prothorax in beetles.

Coarctate. (Lat. *coarcto*, I compress.) The pupa of an insect, which is enveloped by a case, which gives no indication of the parts it covers.

Cœlelmintha. (Gr. *koilos*, hollow; *helmins*, an intestinal worm.) The intestinal worms which are hollow, and contain an alimentary tube in the cavity of the body.

Coleoptera. (Gr. *koleos*, a sheath; *pteron*, a wing.) The order of insects in which the first part of wings serves as a sheath to defend the second pair.

Columella. (From the Latin for a small column.) Used in Conchology to signify the central pillar around which the spiral shell is wound.

Commissural. (Lat. *committo*, I solder.) Belonging to a line or part by which other parts are connected together.

Conchifers. (Lat. *concha*, a shell; *fero*, I bear.) Shell-fish; usually restricted to those with bivalve shells.

Condylopods. (Gr. *kondulos*, a joint; *pous*, a foot.) The articulate animals with jointed legs, as insects, crabs, and spiders.

Coriaceous. (Lat. *corium*, hide.) When a part has the texture of tough skin.

Cornua. (Lat. *cornu*, a horn.) Horns or horn-like processes.

Cornea. (Lat. *corneus*, horny.) The transparent horny membrane in front of the eye.

Corneous. Horny.

Corneule. Diminutive of cornea; applied to the minute transparent segments which defend the compound eyes of insects.

Cretaceous (Lat. *creta*, chalk.) Belonging to chalk.

Crinoid. (Gr. *krinon*, a lily; *eidos*, like.) Belonging to the Echinoderma which resemble lilies; the fossils called stone-lilies or encrinites are examples.

Crura. (Lat. *crus*, a leg.) The legs of an animal, or processes resembling legs.

Crustacea. (Lat. *crusta*, a crust.) The class of articulate animals with a hard skin or crust, which they cast periodically.

Cryptobranchiate. (Gr. *kruptos*, hidden; *bragchia*, gills.) Those molluscous and articulate animals, which have no conspicuous gills.

Cryptogamic. (Gr. *kruptos*, concealed; *gamos*, marriage.) The animals or plants in which the organs of generation are concealed.

Cyclobranchiata. (Gr. *kuklos*, round; *bragchia*, gills.) The molluscous animals which have the gills disposed in a circle.

Decapoda. (Gr. *deca*, ten; *pous*, a foot.) The crustaceous and molluscous animals which have ten feet.

Decollated. (Lat. *decollo*, to behead.) The univalve shells in which the apex or head is worn off in the progress of growth.

Deciduous. Parts which are shed, or do not last the lifetime of the animal.

Dehiscence. (Lat. *dehisco*, to gape.) The splitting open of the bag containing the eggs.

Deflected. Bent down.

Demodex. (Gr. *demos*, lard; *dex*, a boring worm.) The worm-like parasite of the human sebaceous follicles.

Dendritic. (Gr. *dendron*, a tree.) Branched like a tree.

Dermal. (Gr. *derma*, skin.) Belonging to the skin.

Diagnosis. (Gr. *diagignosco*, I distinguish.) The scientific distinction of one animal or part from another, or the definition of its essential characters.

Dibranchiata. (Gr. *dis*, twice; *bragchia*, gills.) The order of Cephalopods having two gills.

Dicœlous. (Gr. *dis*; *koilos*, a cavity.) A heart with two cavities.

Didactyle. (Gr. *dis*; and *dactulos*, a finger.) A limb terminated by two fingers.

Digitate. (Lat. *digitus*, a finger.) When a part supports processes like fingers.

Dimidiate. (Lat. *dimidium*, half.) Divided into two halves.

Diœcious. (Gr. *dis*, twice, and *oikos*, a house.) The species which consist of male and female individuals.

Dimyary. (Gr. *dis*; *muon*, a muscle.) A bivalve whose shell is closed by two muscles.

Diptera. (Gr. *dis*; *pteron*, a wing.) The insects which have two wings.

Discoid. (Lat. *discus*, a quoit.) Quoit-shaped.

Distoma. (Gr. *dis*; *stoma*, mouth.) The intestinal worms with two pores.

Diverticulum. (From the Latin for a bye-road.) Applied to a blind tube branching out from the course of a longer one.

Dorsad. (Lat. *dorsum*, the back.) Towards the back.

Dorsibranchiate. (Lat. *dorsum*; and *bragchia*, gills.) The Mollusca with gills attached to the back.

Dorso-intestinal. A part which is on the dorsal aspect of the intestine.

Ductus. A duct or tube which conveys away the secretion of a gland.

Duodenum. The first portion of the small intestine, which, in the human subject, equals the breadth of twelve fingers.

Ecdysis. (From the Greek, signifying the act of stripping.) Moulting of the skin.

Echinoderms. (Gr. *echinos*, a hedgehog; *derma*, skin.) The class of radiated animals, most of which have spiny skins.

Edentulous. From the Latin word for toothless.

Edriophthalma. (Gr. *edraios*, sitting or sessile; and *ophthalmos*, an eye.) The Crustacea with sessile eyes.

Elytra. (Gr. *elutron*, a sheath.) The wing sheaths formed by the modified anterior pair of wings of beetles.

Emarginate. (Lat. *emargino*, to remove an edge.) When an edge or margin has, as it were, a part bitten out.

Emunctories. (Lat. *emungo*, to wipe the nose.) Parts which carry out of the body useless or noxious particles.

Enaliosaur. (Gr. *enalios*, marine; *sauros*, a lizard.) An extinct order of marine gigantic reptiles allied to crocodiles and fishes.

Encephala. (Gr. *en*, in; *kephale*, head.) The molluscous animals which have a distinct head.

Entomology. (Gr. *entoma*, insects; *logos*, a discourse.) The department of Natural History which treats of insects.

Entomostraca. (Gr. *entoma*, insects; *ostracon*, a shell.) The order of small Crustaceans, many of which are enclosed in an integument, like a bivalve shell.

Entozoa. (Gr. *entos*, within; *zoon*, animal.) The animals which exist within other animals.

Eocene. (Gr. *eos*, the dawn; *kainos*, recent.) The tertiary period, in which the extremely small proportion of living species indicates the first commencement or dawn of the existing state of animate creation.

Epidermal. (Gr. *epidermis*, the cuticle.) Belonging to the cuticle or scarf-skin.

Epimeral. (Gr. *epi*, upon; *meron*, a limb.) The part of the segment of an articulate animal which is above the joint of the limb.

Epiploon. (From the Greek.) It is the fatty membrane which covers or occupies the interspaces of the entrails in the abdomen.

Episternal. (Gr. *epi*, upon; *sternon*, the breast-bone.) The piece of the segment of an articulate animal which is immediately above the middle inferior piece or sternum.

Epithelium. The thin membrane which covers the mucous membranes: it is analogous to the epiderm of the skin.

Epizoa. (Gr. *epi*, upon; *zoon*, animal.) The class of low organised parasitic Crustaceans which live upon other animals.

Errantes. (Lat. *erro*, I wander.) An order of the class Annelida, remarkable for their locomotive powers.

Excito-motory. The function of the nervous system by which an impression is transmitted to a centre, and reflected so as to produce contraction of a muscle without sensation or volition.

Exosmose. (Gr. *ex*, out of; *otheo*, I expel.) The act in which a denser fluid is expelled from a membranous sac by the entry of a lighter fluid from without.

Exuvium. (From the Latin, signifying the skin of a serpent.) The skin which is shed in moulting.

Exuvial. Any part which is moulted.

Facet. (From the French.) A flat surface, with a definite boundary.

Fascicle. (From the Latin *fasciculus.*) A small bundle.

Filiform. (Lat. *filum*, a thread; *forma*, a shape.) Thread-shaped.

Fissiparous. (Lat. *findo*, I cleave; *pario*, I produce.) The multiplication of a species by the self-cleavage of the individual into two parts.

Flabelliform. (Lat. *flabellum*, a fan.) Fan-shaped.

Flagellum. (From the Latin.) An appendage to the legs of the Crustacea resembling a whip.

Flexors. (Lat. *flecto*, I bend.) The muscles employed in bending a limb.

Flexuous. A bending course.

Foliaceous. (Lat. *folium*, a leaf.) Shaped or arranged like leaves.

Follicle. (Lat. *folliculus*, a small bag.) Minute secreting bags which commonly open upon mucous membranes.

Fossiliferous. (Lat. *fossilis*, any thing dug out of the earth; and *fero*, I bear.) Applied to the strata which contain the remains of animals and plants, to which remains Geologists now restrict the term Fossil.

Fucivorous. (Lat. *fucus*, sea-weed; and *voro*, I devour.) Animals which subsist on sea-weed.

Fusiform. (Lat. *fusus*, a spindle; and *forma*, a shape.) Spindle-shaped.

Ganglion. (Gr. *gagglion*, a knot.) A mass of nervous matter, forming a centre from which nervous fibres radiate.

Gastropoda. (Gr. *gaster*, stomach; *pous*, a foot.) That class of molluscous animals which have the locomotive organ attached to the under part of the body.

Gemmiparous. (Lat. *gemma*, a bud; *pario*, I bring forth.) Propagation by the growth of the young, like a bud from the parent.

Gemmule. (Dim. of *gemma.*) The embryos of the radiated animals at that stage when they resemble ciliated monads.

Germen. In plants, the part answering to the ovarium in animals.

Germ-cell. The first nucleated cell that appears in the impregnated ovum, after the reception of the spermatozoon and the disappearance of the germinal vesicle. The germ-cell assimilates the surrounding yolk and propagates its kind by spontaneous fission, whence the first or parent-cell has been termed the "primary germ-cell," and its progeny the "derivative germ-cells."

Germ-mass. The material prepared for the formation of the embryo, consisting of the derivative germ-cells and the yolk which they have assimilated.

Germ-vesicle or Germinal vesicle. The nucleated cell which is the first formed and most essential part of the ovum; it is surrounded by the yolk, and usually passes to the periphery of that part prior to impregnation.

Germ-yolk. That portion of the primary yolk of the egg which is assimilated by the germ-cells in the formation of the germ-mass. In some animals the whole yolk is so assimilated, in others (sepia, *e. g.*) only a small portion, the remainder being the "food-yolk," and absorbed by the future embryo or young animal.

Globose. (Lat. *globus*, a globe.) Globe-shaped.

Glossology. (Gr. *glosse*, the tongue; Gr. *logos*, discourse.) The science of scientific language.

Granules. (Dim. of *granum*, a grain.) Little grains.

Gynglymoid. (Gr. *gigglumos*, a hinge.) A joint formed for motion on one plane.

Haustellate. (Lat. *haurio*, I drink.) The structure of mouth adapted for drinking or pumping up liquids; also the insects which possess that kind of mouth.

Helminthoid. (Gr. *helmins*, an intestinal worm.) Worm-shaped.

Hemelytra. (Gr. *hemisu*, half; *elytron*, a sheath.) A wing, of which one half is opaque and firm like an elytrum.

Hemiptera. (Gr. *hemisu*, half; *pteron*, a wing.) The order of insects in which the anterior wings are hemelytra.

Hepatic. (Lat. *hepar*, liver.) Belonging to the liver.

Herbivorous. (Lat. *herba*, grass; *voro*, I devour.) The animals which subsist on grass.

Hermaphrodite. (*Hermes*, Mercury; *Aphrodita*, Venus.) An individual in which male and female characteristics are combined.

Heterogangliate. (Gr. *heteros*, diverse; *gagglion*.) The animals with the ganglionic nervous system, and the ganglions scattered, often unsymmetrically.

Heteromorphous. (Gr. *heteros*, another; *morphe*, form.) Of an irregular or unusual form, applied to the larvæ of certain insects which differ in form from the imago, and applicable to the true larval state of all insects.

Hexapod. (Gr. *hexa*, six; *pous*, a foot.) The animals with six legs, such as true insects.

Histological. (Gr. *histos*, a tissue; *logos*, discourse.) The doctrine of the tissues which enter into the formation of an animal and its different organs.

Homogangliate. (Gr. *homos*, like; *gagglion*.) The animals with the ganglionic nervous system and symmetrical arrangement of the ganglions.

Homologue. (Gr. *homos*; *logos*, speech.) The same organ in different animals under every variety of form and function.

Homomorphous. (Gr. *homos*, like; *morphe*, form.) Of similar form.

Homoptera. (Gr. *homos*, like; *pteron*, a wing.) The insects in which the four wings have a similar structure, but restricted, in its application, to a section of Hemiptera.

Hyaline. (Gr. *hualos*, crystal.) The pellucid substance which determines the spontaneous fission of cells.

Hydatid. (Gr. *hudatis*, a vesicle.) A bladder of albuminous membrane, containing serous fluid; generally detached; sometimes with an organised head and neck.

Hydra. (Gr. *hudra*, a water-serpent.) The modern generic name of certain freshwater Polypes.

Hydriform. Similarly-formed Polypes to the Hydræ.

Hydrozoa. (Gr. *hudra*; *zoon*, animal.) The class of Polypi organised like the Hydra.

Hymenoptera. (Gr. *humen*, a membrane; *pteron*, a wing.) The order of insects including the bee, wasp, &c. which have four membranous wings.

Imbricated. (Lat. *imbricatus*, tiled.) Scales which lie one upon another like tiles.

Ingluvies. A crop or partial dilatation of the œsophagus.

Inopercular. Univalve shells which have no operculum or lid.

Instrumenta Cibaria. (Lat. *cibus*, food.) The parts of the mouth in insects concerned in the acquisition and preparation of the food.

Interambulacra. The imperforate plates which occupy the intervals of the perforated ones, or ambulacra, in the shells of the Echinoderms. See *Ambulacra*.

Interganglionic. (Lat. *inter*, between; and *gagglion*.) The nervous chords in the intervals of the ganglions, which they connect together.

Interstitial. (Lat. *interstitium*.) Relating to the intervals between parts.

Intra-uterine. (Lat. *intra*, within; *uterus*, the womb.) That which is, or takes place, within the womb.

Intussusception. (Lat. *intus*, within; *suscipio*, I take up.) The act of taking foreign matter into a living being. Also the state of a part of a tube when it is inverted within a contiguous part.

Invaginated. (Lat. *in*; *vagina*, a sheath.) When a part is contained in another, as in a sheath.

Invertebrata. (Lat. *in*, used in composition to signify *not*, like *un*; *vertebra*, a bone of the back.) Animals without back-bones.

Isocyclous. (Gr. *isos*, equal; *kuklos*, a ring.) An animal composed of a succession of equal rings.

Isopoda. (Gr. *isos*, equal; *pous*, a foot.) An order of Crustaceans in which the feet are alike, and equal.

Labium. Latin for a lip; but applied only to the lower lip in Entomology.

Labrum. Latin for a lip; but applied only to the upper lip in Entomology.

Lamellibranchiata. (Lat. *lamella*, a plate; *bragchia*, gills.) The class of acephalous Mollusks with gills in the form of membranous plates.

Lamelliform. Shaped like a thin leaf or plate.

Laniariform. (Lat. *lanio*, to cut or tear; *forma*, shape.) Shaped like the canine teeth of the Carnivora, which are called *laniaries* from their office.

Larva. (Lat. *larva*, a mask.) Applied to an insect in its first active state, which is generally different from, and as it were masks the ultimate form. Larviform, shaped like a larva.

Larviparous. (Lat. *larva; pario*, I produce.) The insects which produce their young in the condition of larvæ.

Lemniscus. (The Latin for riband.) Applied to the minute riband-shaped appendages of the generative pores in *Entozoa*.

Lepidoptera. (Gr. *lepis*, a scale; *pteron*, a wing.) The order of insects in which the wings are clothed with fine scales, as butterflies and moths.

Macroura. (Gr. *makros*, long; *oura*, tail.) The tribe of decapod Crustacea which have long tails, as the lobster.

Malacology. (Gr. *malakos*, soft; *logos*, discourse.) The history of the soft-bodied or molluscous animals, which were termed *Malakia* by Aristotle.

Malacostraca. (Gr. *malakos; ostrakon*, a shell.) The name given by Aristotle to the modern Crustacea, because their shells were softer than those of the Mollusca, or ordinary shell-fish.

Mammalia. (Lat. *mamma*, a breast.) The class of animals which give suck to their young.

Mandibulata. (Lat. *mandibula*, a jaw.) The insects which have mouths provided with jaws for mastication; the term mandible is restricted in Entomology to the upper and outer pair of jaws.

Mantle. The external soft contractile skin of the Mollusca, which covers the viscera and a great part of the body like a cloak.

Marsupial. (Lat. *marsupium*, a purse.) The tegumentary pouch, in which the embryo is received after birth, and protected during the completion of its development.

Mastodon. (Gr. *mastos*, a teat; *odon*, a tooth.) A genus of extinct quadrupeds allied to the elephant, but having the grinders covered with conical protuberances like teats.

Maxilla. (From the Latin for a jaw.) In Entomology restricted to the inferior pair of jaws.

Median. Having reference to the middle line of the body.

Medulla oblongata. The oblong medullary column at the base of the brain, from which the spinal chord or marrow is continued.

Medusæ. A genus or family of soft radiated animals or acalephes, so called because their organs of motion and prehension are spread out like the snaky hair of the fabulous Medusa.

Mesentery. (Gr. *mesos*, intermediate; and *enteros*, entrail.) The membrane which forms the medium of connection between the small intestines and the abdomen.

Mesogastric. (Gr. *mesos;* and *gaster*, stomach.) The membrane which forms the medium of attachment of the stomach to the walls of the abdomen.

Mesonotum. (Gr. *mesos*, middle; *notos*, back.) The middle piece of that half of segment which covers the back.

Mesosternum. (Gr. *mesos; sternon*, breast.) The middle part of that half of the segment which covers the breast.

Mesothorax. (Gr. *mesos*, middle; and *thorax*, the chest.) The intermediate of the three segments which form the thorax in insects.

Metabola. (Gr. *metabolé*, change.) Those insects which undergo a metamorphosis.

Metagenesis. (Gr. *meta*, indicating change; *gignomai*, I produce.) The changes of form which the representative of a species of animal or plant undergoes in passing by a series of successively generated individuals from the egg to the mature or imago state. It is distinguished from "metamorphosis," in which these changes are undergone in the same individual.

Metamorphosis. (Gr. *meta*, signifying change; and *morphe*, form.) The change of form which the individual of certain species undergoes in passing from one stage of existence to another.

Metathorax (Gr. *meta*, after; *thorax*.) The hindmost of the three segments which compose the thorax of an insect.

Miocene. (Gr. *meion*, less; *kainos*, recent.) The tertiary epoch in which a minority of fossil shells are of the recent species.

Molecules. (Dim. of *moles*, a mass.) Microscopic particles.

Mollusca. (Lat. *mollis*, soft.) The primary division of the Animal Kingdom, characterised at page 13.

Monad. (Gr. *monas*, unity.) The genus of the most minute and simple microscopic animalcules, shaped like spherical cells. Monadiform, like a monad.

Monadiary. The common envelope of many organically associated monads.

Moniliform. (Lat. *monile*, a necklace.) A structure like a necklace or string of beads.

Monocarpous. (Gr. *monos*, single; *carpos*, fruit.) An animal or plant which perishes when they have once borne fruit.

Monoculus. (Gr. *monos*, single; Lat. *oculus*, an eye.) The animals which have but one eye.

Monœcious. (Gr. *monos*, single; and *oikos*, house.) Organisms whose structure is both male and female.

Monomyary. (Gr. *monos*, single; *muon*, a muscle.) A bivalve whose shell is closed by one adductor muscle.

Monothalamous. (Gr. *monos*; *thalamos*, a chamber.) A shell forming a single chamber, like that of the whelk.

Morphology. (Gr. *morphe*, form; *logos*, discourse.) The history of the modifications of form which the same organ undergoes in the same or in different organisms.

Motory. The nerves which excite and control motion.

Multivalve. (Lat. *multus*, many; *valvæ*, folding-doors.) Shells composed of many pieces or valves.

Myelencephala. (Gr. *muelos*, marrow; *egkephalon*, brain.) The primary division of animals characterised by a brain and spinal marrow.

Myriapoda. (Gr. *murios*, ten thousand; *pous*, foot.) The order of insects characterised by their numerous feet.

Nacreous. Pearly, like mother-of-pearl.

Natatory. An animal or part formed for swimming.

Nematoidea. (Gr. *nema*, a thread; *eidos*, like.) The intestinal worms, which are long, slender, and cylindrical like threads.

Nematoneura. (Gr. *nema*, a thread; *neuron*, a nerve.) The animals in which the nervous system is filamentary, as in the star-fish.

Nervures. (Lat. *nervus*, a sinew.) The delicate frame-work of the membranous wings of insects.

Neurilemma. (Gr. *neuron*, a nerve; *lemma*, a covering.) The membrane which surrounds the nervous fibre.

Neurology. (Gr. *neuron*, a nerve; *logos*, a discourse.) The science of the nervous system.

Neuroptera. (Gr. *neuron*, a nerve; *pteron*, a wing.) The order of insects with four wings, characterised by their numerous nervures, like those of the dragon-fly.

Nidamental. (Lat. *nidus*, a nest.) Relating to the protection of the egg and young, especially applied to the organs that secrete the material of which many animals construct their nests.

Nodule. (Dim. of *nodus*, a knot.) A little knot-like eminence.

Normal. (Lat. *norma*, rule.) According to rule, ordinary or natural.

Notal. (Gr. *notos*, the back.) Belonging to the back.

Nucleated. Having a nucleus or central particle; applied to the elementary cells of animal tissues, the most important properties of which reside in the nucleus.

Nudibrachiate. (Lat. *nudus*, naked; *brachia*, arms.) The Polypes, whose arms are not clothed with vibratile cilia.

Nudibranchiate. (Lat. *nudus*, naked; *bragchia*, gills.) An order of Gastropods in which the gills are exposed.

Octopoda. (Gr. *octo*, eight; *pous*, a foot.) Animals with eight feet. The name of the tribe of Cephalopods with eight prehensile organs attached to the head.

Œsophagus. The gullet or tube leading from the mouth to the stomach.

Olfactory. (Lat. *olfactus*, the sense of smelling.) Relating to that sense.

Onychoteuthis. (Gr. *onux*, a hook; *teuthis*, a calamary.) The genus of Calamaries armed with hooks or claws.

Oolite. (Gr. *oon*, egg; *lithos*, stone.) An extensive group of secondary limestones, some of which are composed of rounded particles, like the roe or eggs of a fish.

Operculum. (From the Latin for lid.) Applied to the horny or shelly plate which closes certain univalve shells; also to the covering of the gills in fish, and to the lids of certain eggs.

Oral (Lat. *os*, the mouth.) Belonging to the mouth or to speech.

Orthocera and **Orthoceratite.** (Gr. *orthos*, straight; *keras*, horn.) The extinct Cephalopods which inhabited long conical chambered shells like a straight horn.

Orthoptera. (Gr. *orthos*, straight; *pteron*, a wing.) The order of insects, with elytra and longitudinally folded wings.

Osseous. (Lat *os*, a bone.) Bony.

Otolithes. (Gr. *ous*, an ear; *lithos*, a stone.) The stony or chalky bodies belonging to the internal ear.

Ovarium. (Lat. *ovum*, an egg.) The organ in which the eggs or their elementary and essential parts are formed.

Ovicapsule. (Lat. *ovum*, an egg; *capsula*, a bag.) An egg-bag formed by some membrane or secretion of the animal.

Ovigerous. (Lat. *ovum*, an egg; *gero*, I bear.) Animals or parts containing or supporting eggs.

Oviparous. (Lat. *ovum*; *pario*, I bring forth.) The animals which bring forth eggs.

Ovipositor. (Lat. *ovum*; *pono*, I place.) The organ in insects, which is often large and complicated, for the transmission of the eggs, during exclusion, to their appropriate place.

Ovoviviparous. (Lat. *ovum*, egg; *vivus*, alive; *pario*, I produce.) The animals which produce living young, hatched in the egg within the body of the parent, without any connection with the womb.

Palæontology. (Gr. *palaios*, ancient; *onta*, beings; *logos*, discourse.) The history of ancient extinct organised beings.

Pallial. (Lat. *pallium*, a cloak.) Relating to the mantle or cloak of the Mollusca.

Palliobranchiata. (Lat. *pallium*; *bragchia*, gills.) The class of acephalous Mollusca in which the gills are developed from the mantle.

Palpi. (Lat. *palpo*, I touch.) The organs of touch developed from the labium and maxillæ of insects.

Papilla. (Lat. for nipple.) Minute soft prominences generally adapted for delicate sensation.

Papyraceous. (Gr. *papuros*, paper.) Of the consistency of paper.

Parenchyma. The soft tissue of organs; generally applied to that of glands.

Parietes. (Lat. *paries*, a wall.) The walls of the different cavities of an animal body.

Parthenogenesis. (Gr. *parthenos*, a virgin; *gignomai*, to be born.) Propagation by self-splitting or self-dividing, by budding from without or within, and by any mode save by the act of impregnation; the parthenogenetic individuals being sexless or virgin females.

Pectinated. (Lat. *pecten*, a comb.) Toothed like a comb.

Pectinibranchiata. (Lat. *pecten*, a comb; *bragchia*, gills.) The order of Gastropods in which the gills are shaped like a comb.

Pediform. (Lat. *pes*, a foot.) Shaped like a foot.

Peduncle. From the Latin *pedunculus*, a stalk.

Pedunculated. Suspended or supported by a stalk.

Pelagic. (Gr. *pelagos*, sea.) Belonging to the deep sea.

Pentacrinite. (Gr. *penta*, five ; *krinos*, hair.) A pedunculated star-fish with five rays : they are, for the most part, fossil.

Pergameneous. (Lat. *pergamen*, parchment.) Of the texture of parchment.

Periostracum. (Gr. *peri*, around ; *ostrakon*, shell.) The membrane analogous to scarf-skin, which covers shell.

Peristaltic. (Gr. *peri* ; *stello*, to range.) The vermicular contractions and motions of muscular canals, as the alimentary, the circulating, and generative tubes.

Peritoneal. (Gr. *peritonaios*, the covering of the abdomen.) Restricted to the lining membrane of that cavity.

Peritrema. (Gr. *peri*, around ; *trema*, hole.) The raised margin which surrounds the breathing holes of scorpions.

Petiolate. (Lat. *petiolus*, a fruit stalk.) Ducts supported or suspended by a slender stalk.

Pharynx. The dilated beginning of the gullet.

Pharyngeal. Belonging to the pharynx.

Phragmocone. (Gr. *phragma*, a partition ; *konos*, a cone.) The chambered cone of the shell of the Belemnite.

Physograde. (Gr. *physis*, air ; and *gradior*, I proceed.) The Acalephes that swim by means of air-bladders.

Phytophagous. (Gr. *phuton*, a plant ; *phago*, I eat.) Plant-eating animals.

Pigmental. (Lat. *pigmentum*, paint.) The cells which secrete the coloured particles of the skin and eye, and the membrane formed by such cells.

Pinnate. (Lat. *pinna*, a feather or fin.) Shaped like a feather, or provided with fins.

Planula. (Lat. *planus*, flat.) A name applied to the flat ciliated form of larva, under which many polypes first quit the egg.

Plasma. (Gr. *plasma*, mouldable matter.) The fluid part of the blood, in which the red corpuscles float : also called *liquor sanguinis*

Plastron. The under part of the shell of the crab and tortoise.

Plexus. (Gr. *pleko*, I twine.) A bundle of nerves or vessels interwoven or twined together.

Pleiocene. (Gr. *pleion*, more ; *kainos*, recent.) The tertiary strata, which are more recent than the miocene, and in which the major part of the fossil testacea belong to recent species.

Pleistocene. (Gr. *pleistos*, most ; *kainos*, recent.) The newest of the tertiary strata, which contains the largest proportion of living species of shells.

Plicæ. (Lat. *plica*, a fold.) Folds of membrane.

Plumos. (Lat. *pluma*, a feather.) Feathery, or like a plume of feathers.

Pneumatic. (Gr. *pneuma*, breath.) Belonging to the air and air-breathing organs.

Podophthalma. (Gr. *pous*, a foot ; *ophthalmos*, an eye.) The tribe of Crustacea in which the eyes are supported upon stalks.

Polygastria. (Gr. *polus*, many ; *gaster*, a stomach.) The class of infusorial animalcules which have many assimilative sacs or stomachs.

Polypi. (Gr. *polus* ; *pous*, a foot.) The class of zoophytes with many prehensile organs radiating from around the mouth.

Prolegs. The wart-like tubercles which represent legs on the hinder segment of caterpillars.

Prothorax. (Gr. *pro*, before, and *thorax*.) The first of the three segments which constitute the thorax in insects.

Psychical. (Gr. *psuche*, the soul.) Relating to the phenomena of the soul, and to analogous phenomena in the lower animals.

Pteropoda. (Gr. *pteron*, a wing ; *pous*, a foot.) The class of Mollusca in which the organs of motion are shaped like wings.

Pulmograde. (Lat. *pulmo*, a lung ; *gradior*, I walk.) The tribe of Medusæ which swim by contractions of the respiratory disc.

Pulmonata. (Lat. *pulmo*.) The order of Gastropods that breathe by lungs.

Pupa. (From the Latin for a doll or little image.) The passive state of an insect immediately preceding the last.

Pupiparous. (Lat. *pupa; pario*, I produce.) The insects that bring forth their young in the pupa state.

Pylorus. From the Greek. The aperture which leads from the stomach to the intestines.

Pyriform. (Lat. *pyrum*, a pear.) Pear-shaped.

Quadrifid. Cleft in four parts.

Quaternary. In chemistry, bodies composed of four elementary substances.

Radiata. (Lat. *radius*, a ray.) The name of the lowest primary division of the animal kingdom.

Ramose. (Lat. *ramus*, a branch.) Branched.

Reniform. (Lat. *ren*, a kidney.) Kidney-shaped.

Reptilia. (Lat. *repto*, I creep.) The class of Vertebrate animals with imperfect respiration and cold blood.

Rete Mucosum. The cellular layer between the scarf-skin and true skin, which is the seat of the peculiar colour of the skin.

Rhyncholithes. (Gr. *rhunchos*, a beak ; *lithos*, a stone.) Beak-shaped fossils ; the extremities of the mandibles of Cephalopods, allied to the Nautilus.

Rotifera. (Lat. *rota*, a wheel ; *fero*, I bear.) The name of the class of infusorial animalcules, characterised by the vibratile and apparently rotating ciliary organs upon the heads.

Salpians. (Gr. *Salpe*, a kind of fish.) The order of tunicated Mollusca which float in the open sea.

Sarcophaga. (Gr. *sarx*, flesh ; *phago*, I eat.) Flesh-eating animals.

Sacciform. Shaped like a sac or bag.

Scutibranchiata. (Lat. *scutum*, a shield ; *bragchia*, gills.) The order of gastropodous Mollusca, in which the gills are protected by a shield-shaped shell.

Sebaceous. (Lat. *sebum*, tallow.) Like lard or tallow.

Segmentation. The act of dividing into segments.

Semilunar. Crescent-shaped, like a half-moon.

Semipinnate. Fringed on one side.

Sepal. The divisions of the calyx of a flower.

Septa. Partitions.

Sericteria. (Gr. *serikos*, silky.) The glands which secrete the silk in the silkworm.

Serrated. (Lat. *serra*, a saw.) Toothed like a saw.

Sessile. Attached by a base.

Setæ. (From the Latin for a bristle.) Bristles, or similar parts.

Setigerous. Bristly.

Siliceous. (Lat. *silex*, flint.) Flinty.

Sinus. A dilated vein or receptacle of blood.

Siphonostomous. (Gr. *siphon*, a tube ; *stoma*, a mouth.) Animals furnished with a suctorious mouth like a tube. The term is usually applied to Crustacea so characterised.

Spatulate. (Lat. *spatula*.) Shaped like a spatula.

Spermatheca. (Gr. *sperma*, seed ; *theke*, sheath.) A receptacle attached to the oviducts of insects.

Spermatoa. (Gr. *sperma*, and *oon*, an egg.) The nucleated cell in which the spermatozoon is developed.

Spermatophora. (Gr. *sperma; phero*, I bear.) The cylindrical capsules or sheaths which convey the sperm. In the Cephalopods are called the moving filaments of Needham, after their discoverer.

Spermatozoa. (Gr. *sperma* ; *zoon*, an animal.) The peculiar microscopic moving filaments and essential parts of the fertilizing fluid.

Sphincter. (Gr. *sphigkter*.) The circular muscles which contract or close natural apertures.

Spicula. (Lat. *spiculum*, a point or dart.) Fine pointed bodies like needles.

SPINNARET. The articulated tubes with which spiders fabricate their webs.

SPIRACLES. (Lat. *spiro*, I breathe.) The breathing pores in insects.

SQUAMOUS. (Lat. *squama*, a scale.) Arranged like scales.

STEMMATA. (Lat. *stemma*.) The simple and minute eyes of worms, and those which are added to the large compound eyes.

STERELMINTHA. (Gr. *stereos*, solid; *helmins*, an intestinal worm.) Intestinal worms which have no true abdominal cavity, and which were called "parenchymatous" by Cuvier, as the tape-worms.

STERNAL. The aspect of the body where the sternum or breast bone is situated.

STIGMATA. (Gr. *stigma*, a mark.) The breathing pores of insects.

STOMATO-GASTRIC. (Gr. *stoma*, a mouth; *gaster*, a stomach.) The system of nerves which are principally distributed upon the stomach and intestinal canal.

STREPSIPTERA. (Gr. *strepho*, I twist; *pteron*, a wing.) The singular order of insects discovered by Mr. Kirby, in which the first pair of wings is represented by twisted rudiments.

SUBMUSCULAR. Beneath muscles or muscular layers.

SUBŒSOPHAGEAL. Beneath the gullet.

SUCTORIA. (Lat. *sugo*, I suck.) The animals provided with mouths for sucking, and the appendages of other parts organised for sucking or adhesion.

SUPERŒSOPHAGEAL. Above the gullet.

SUTURAL. Appertaining to a suture.

SUTURE. (Lat. *suo*, I sew.) The immoveable junction of two parts by their margins.

TÆNIOID. (Gr. *tainia*, a riband; *eidos*, like.) Riband-shaped, like the Tænia or tape-worm.

TAPETUM. (Lat. *tapetum*, a carpet.) The coloured layer of the choroid coat of the eye.

TARSUS. (Gr. *tarsos*, a part of the foot.) Applied to the last segments of the legs of insects.

TECTIBRANCHIATE. (Lat. *tego*, I cover; *bragchia*, gills.) The order of Mollusca in which the gills are covered by the mantle.

TERGAL. (Lat. *tergum*, the back.) Belonging to the back.

TETRABRANCHIATE. (Gr. *tetra*, four; *bragchia*, gills.) The order of Cephalopods with four gills.

TEUTHIDÆ. (Gr. *teuthis*, a calamary.) The family of Cephalopods, of which the calamary is the type.

THORACIC. Belonging to the thorax.

THYSANOURA. (Gr. *thusanoi*, fringes; *oura*, a tail.) A family of apterous insects with fringed tails.

TRACHEÆ. (Gr. *tracheia*, the rough artery or windpipe.) The breathing tubes of insects.

TRACHELIPODS. (Gr. *trachelos*, the neck; *pous*, a foot.) The Mollusca which have the locomotive disc or foot attached to the side of the neck.

TREMATODA. (Gr. *trema*, a pore.) The order of Entozoa characterised by suctorial pores.

TRENCHANT. Sharp edged, cutting.

TRIDACTYLE. Three-fingered.

TRILOBATE. Divided into three lobes.

TRILOBITE. An extinct genus of Crustacea, the upper surface of whose body is divided into three lobes.

TRIRADIATE. Consisting of three spokes or rays.

TROPHI. (Gr. *trophos*, a nourisher.) In insects, the parts of the mouth employed in acquiring and preparing the food.

TUBERCULATE. Warty, or covered with small rounded knobs.

TUNICATA. (Lat. *tunica*, a cloak.) The class of acephalous Mollusca which are enveloped in an elastic tunic not defended by a shell.

UNCINATED. Beset with bent spines like hooks.

UNIVALVE. (Lat. *unus*, one; *valvæ*, doors.) A shell composed of one calcareous piece.

Vasiform. (Lat. *vas*, a vessel.) Shaped like a bloodvessel or tube.

Ventral. Relating to the inferior surface of the body.

Ventricular. (Lat. *ventriculus*, a ventricle or small cavity, like those of the heart or brain.) Belonging to a ventricle.

Vermes. (Lat. *vermis*, a worm.) Worm-like animals: applied in a very extensive sense by Linnæus.

Vertebrata. (Lat. *vertebra*, a bone of the back; from *vertere*, to turn.) The highest division of the Animal Kingdom, characterised by having a back-bone.

Verticillate. (Lat. *verticillus*, a whirl.) Arranged like the rays of a wheel or spindle.

Vermiform. Worm-shaped.

Vesiculæ. (Lat. *vesica*, a bladder.) Receptacles like little bladders.

Villi. Small processes like the pile of velvet.

Vitelline. (Lat. *vitellus*, yolk.) Of or belonging to the yolk.

Viviparous. (Lat. *vivus*, alive; *pario*, I bring forth.) The animals which bring forth their young alive.

Whorl. The spiral turn of a shell, and the like arrangement of a group of leaves or polypes upon a stem.

Whorling. The act of disposing parts in a series of spiral curves round an axis.

Xiphosura. (Gr. *xiphos*, a sword; *oura*, a tail.) A family of Crustacea with sword-shaped tails, as the Limulus.

Zoophyte. (Gr. *zoon*, animal; *phyton*, plant.) The lowest primary division of the Animal Kingdom, which includes many animals that are fixed to the ground and have the form of plants.

Zoospore. (Gr. *zoon*, animal; *spora*, seed.) The reproductive bodies of sexless water-plants, which enjoy the power of locomotion for a certain time.

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THE END.

ERRATA.

Page 13. last line of Note*, for “pl. i. of the present volume,” read “pl. iii. of ccciii.’
Page 51. line 24. after Cirripedes a full-stop, and dele to “species at line 27.”

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